Smart Healthy Environments 2024

Exploring Healthy living through Living Lab realm.

1st international scientific conference

SHE2024

Maastricht, the Netherlands, May 14 -16, 2024

Proceedings

ICT Healthy living &

SHE SCIENTIFIC CONFERENCE

Colophon

Book of Proceedings

Smart Healthy Environments 2024

Exploring Healthy living through Living Lab realm

1st international scientific conference, SHE2024

Maastricht, the Netherlands, May 14-16, 2024

Editors

Prof. dr. ir. Masi Mohammadi

Eindhoven University of Technology, HAN University of Applied Sciences, DEEL

Ir. Leonie van Buuren, EngD, PhD candidate

Eindhoven University of Technology

Moniek van Loon, MSc

HAN University of Applied Sciences

Design

Ir. Laurèn Pennings, MSc & Julia Rienks, BSc

Eindhoven University of Technology

Eindhoven University of Technology, May 2024

Second edition

A catalogue record is available from the Eindhoven University of Technology Library

ISBN: 978-90-386-6054-7

Visit www.SHEworldconference.com/proceedings

Preface

Dear colleagues, researchers, collaborators, and esteemed readers,

It is with deep satisfaction and gratitude that I write this foreword to the Proceedings of the International Conference on Smart Healthy Environments. At SHE2024, we transcend traditional boundaries in our quest to foster healthy living and the creation of places dedicated to sustainable happiness. This event heralds a profound exploration into the integration of the built environment, healthcare, and technological innovations, aiming to cultivate settings that enhance individual well-being and enrich our collective living experience.

Living Labs emerge as pivotal, serving as transformative platforms where we confront global challenges such as the complexities of aging societies, socioeconomic health disparities, and the urgent need for sustainable, human-centered solutions. Our commitment extends beyond personal well-being, nurturing social capital within communities and emphasizing the imperative to reinforce our care systems while respecting the natural world. Through interdisciplinary efforts, we devise solutions that bolster not only individual health but also enhance the collective well-being of our communities, maintaining a balance with the environment.

The conference spans three days, each crafted to address the multifaceted and complex domains of Smart Healthy Environments. We begin by highlighting the technological innovations and their integration into socio-organizational contexts. The second day focuses mainly on social value and challenges of this dynamic research area. The culmination on the third day synthesizes science, practice, and policy in the realm of healthy smart living, featuring a special hybrid component organized by our esteemed colleagues from Zuyd University of Applied Sciences, The Hague University of Applied Sciences, HAN University of Applied Sciences and Eindhoven University of Technology. This segment enriches our collective experience, merging technological advancements with international collaboration.

We are privileged to collaborate with a distinguished cross-disciplinary team of academics directly engaged in this societal transformation towards smart and healthy living. Our partners come from esteemed institutions, including RMIT Europe, RISE Research Institutes of Sweden, Simon Fraser University, Health~Holland, SIA, Leiden University Medical Center, Technalia, Taskforce for Applied Research SIA, Agile Ageing Alliance, and the European Network of Living Labs. Alongside these academics, numerous professionals from policy and practice, including Platform 31, AFEdemy, ICT & Health, the organizations and Living Labs affiliated with DEEL, and last but not least, the citizen and patient organizations have greatly enriched this conference with their contributions.

These contributions underscore the necessity for a broad perspective and scientific rigor, while simultaneously ensuring the scientific reliability and depth of the conference. They introduce new approaches for building inclusion and communities and the systemic changes that are crucial for enhancing living spaces for all, including those with dementia, and for developing inclusive housing and neighborhoods that ensure safety, care, and social engagement.

I extend heartfelt thanks to all our supporters, including HAN University of Applied Sciences, and special thanks are due to my co-organizers, Leonie van Buuren, Moniek van Loon, and Toine van Lieshout for their relentless efforts.

As we reflect on the discussions and insights shared at SHE2024, we are reminded of our shared commitment to transform the living environment into a dynamic and empowering space. This proceedings book not only captures the essence of our collaborative explorations but also serves as an encouragement for future endeavors in creating smart, healthy environments.
Wishing you lots of insight and inspiration as you read through this proceedings book.

Prof. dr. ir. Masi Mohammadi
Chair, SHE2024 Smart Healthy Environments International Scientific Conference

Organization

Scientific board

Prof. dr. ir. Masi Mohammadi | Conference chair, DEEL, The Netherlands

Prof. dr. Niels Chavannes | NeLL National eHealth Living Lab, The Netherlands

Camilla Evensson, MSc | RISE Research Institutes of Sweden, Sweden

Prof. dr. Tineke Abma | Leyden Academy, LUMC, The Netherlands

Prof. dr. Marta Fernández | RMIT Europe, Spain

Prof. dr. ir. Gloria Gutma | Simon Fraser University

Prof. dr. Nico van Meeteren | Health~Holland, The Netherlands

Organizing committee

Prof.dr.ir. Masi Mohammadi | Conference chair, DEEL

Ir. Leonie van Buuren, EngD | Eindhoven University of Technology, The Netherlands

Moniek van Loon, MSc | HAN University of Applied Sciences, The Netherlands

Ing. Toine van Lieshout | HAN University of Applied Sciences, The Netherlands

Organization committee online day May 16th

Dr. Nurhan Abujidi Rizal | Zuyd University of Applied Sciences, The Netherlands

Dr. Rizal Sebastian | The Hague University of Applied Sciences, The Netherlands

Ir. Peyman Najafi | Eindhoven University of Technology, The Netherlands

Review committee

Dr.ir. Olivia Guerra-Santin | Eindhoven University of Technology, The Netherlands

Dr. Nienke Moor | HAN University of Applied Sciences, The Netherlands

Dr. Ignacio Pedrosa | CTIC Technology Centre, Spain

Dr. Sander van de Hoef | HU University of Applied Sciences Utrecht, The Netherlands

Dr.ir. Pauline van den Berg | Fontys University of Applied Sciences, The Netherlands

Dr. Pai Liu | Eindhoven University of Technology, The Netherlands

Dr. ir.-arch. Sara Willems | KU Leuven, Belgium

Dr.ir. Simone de Bruin | Windesheim University of Applied Sciences, The Netherlands

Prof.dr. Daantje Derks | Erasmus University Rotterdam, The Netherlands

Dr. Joanna Syrda | University of Bath, England

Dr. Nurhan Abujidi | Zuyd University of Applied Sciences, The Netherlands

Dr. Rizal Sebastian | The Hague University of Applied Sciences, The Netherlands

Dr. Louis Neven | HAN University of Applied Sciences, The Netherlands

Table of contents

1

Empathic & caring living environment

1 Emphatic & caring living environment: **Conference paper**

The impact of types of residential buildings on older adults' social interactions in Dutch social housing

Kim Hamers[1,2]*, Nienke Moor[1], Theo Arentze[3], Masi Mohammadi[1,2]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] The Chair of the Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[3] Chair of the Real Estate Management and Development, Eindhoven University of Technology, The Netherlands

*Corresponding author: Kim Hamers (kim.hamers@han.nl)

Abstract: Housing associations are dealing with a growing number of older tenants who are aging in place. As they age, this group of older adults may be at increased risk of reduced self-reliance and loneliness. However, the current Dutch social housing stock appears to support the (social) needs of older residents insufficiently. Therefore, housing associations are interested in residential environments that facilitate (organized) encounters between residents. The underlying assumption is that residents who are living in a building type that facilitates encounters better, keep an eye on each other more and help out more often. To gain more knowledge about the relationship between building type and neighborly contact, we compared four groups of older residents living in a different building type, based on survey data from older tenants (55+) from housing association Woonzorg Nederland (N=2,852). The findings show that older adults who live in low-rise buildings with a communal space for socializing interact more frequently with fellow residents than older adults who live in one of the other building types. Older adults who live in a high-rise building without a communal space for socializing are least likely to have friendly contact with fellow residents. Finally, it is striking that there is a small group of residents who rarely have any contact at all with other residents, regardless of the extent to which the residential building facilitates encounters.

Keywords: building type; social housing; encounters; social interaction; older adults

1. Introduction

In the Netherlands, a growing number of older adults is aging in place, as a result of demographic developments and Dutch government policies regarding housing and care. From the perspective of citizen participation, older people nowadays should be more dependent on their social network when they encounter physical, mental and/or social vulnerabilities

(Glendinning & Moran, 2009; Grootegoed & Van Dijk, 2012). However, not only does the share of single-person households increase as older adults age, but the size of the social network also tends to decrease with advancing age (Wrzus et al., 2013). Together with the declining fertility rates in the Netherlands, this can result in a vulnerable social network of older people in which only a limited number of immediate family members and friends can take on the role of informal caregiver (Doekhie et al., 2014). This development increases the demand for a residential environment for older adults that facilitates and promotes social interaction in the neighborhood. Especially because as people get older, partly due to mobility problems, the importance of having a social network within the immediate living environment increases (Thomese, 1998).

Housing associations are also experiencing a shift in their resident population towards an increasingly large group of older tenants. In 2020, just over a million Dutch social homes accommodated a senior household (Ministry of the Interior and Kingdom Relations, 2023). This group of older adults often has fewer (financial) resources for arranging a suitable residential environment that supports ageing in place in a pleasant way. Housing associations and their partners can play an important role by designing residential environments and neighborhoods that encourage encounters between residents (Ministry of the Interior and Kingdom Relations, 2022). An underlying assumption is that contact between residents can promote neighboring activities and neighborly support, which positively affects the well-being of older adults (Cramm et al., 2013). However, much is still unknown about the impact of the type of housing (in the social rental sector) on the extent to which and how (organized) meetings between residents take place. Therefore, our research question reads: *Do residents of building types that spatially facilitate encounters between residents have more (friendly) neighborly contact compared to residents of building types that do not?*

2. Methods

2.1 Data & operationalization

For this study, data was collected among independently living tenants of the housing association Woonzorg Nederland, which specifically focuses on senior housing (55+). In the summer of 2022, research agency MAGIS Marketing & Research approached the main tenants of approximately 14,900 households that rented a home from Woonzorg Nederland by email. About 3,700 tenants completed the online questionnaire. Respondents were asked, among other things, about the frequency and nature of contact with fellow residents (within the residential building). Background characteristics, such as gender, household situation, age, level of education, perceived health, and social attitude, were also questioned.

In an earlier phase of the research, characteristics of residential buildings within the housing stock of Woonzorg Nederland and their resident groups were collected among building managers of this housing association. Building managers are regularly present at the buildings of the housing association for which they are responsible concerning technical and social management. In an online survey in 2020, they were asked about socio-spatial characteristics of the residential building and the resident group living there. In 2022 a second invitation was sent to building managers who did not respond the first time.

For the purpose of this study, the real estate data from the housing association and the data collected among building managers were then linked to the survey data from tenants. After cleaning the combined dataset and excluding respondents under the age of 55 and those living in a single-family house, a dataset remains with information on 2,852 respondents living in residential buildings. In the results section, the findings of this study are illustrated with quotes from interviews conducted with tenants of three residential buildings of Woonzorg Nederland in the period between February 2022 to February 2024.

2.2 Building types

From scientific studies, we know that specific spatial characteristics in the residential environment can facilitate or even stimulate social interaction between residents. The first important variable in this regard is the presence of a communal space in the residential building for socializing (Tyvimaa, 2011; Williams, 2005). To underline the importance of this, in 2022 and 2023 the Dutch government provided financial support to 84 housing associations in the renovation or new construction of 195 communal areas for older adults where they can meet (Ministry of the Interior and Kingdom Relations, 2024). Another spatial variable related to the likelihood of residents interacting is building height (the number of floors). Kearns et al. (2003) show in their research that people who live in high-rise buildings have less frequent contact with their fellow residents than people who live in low-rise buildings or single-family homes. Because the housing stock of the housing association involved includes both low-rise and high-rise buildings, it is interesting to include this spatial characteristic as a second variable in the analysis.

This article specifically looks at combinations of the two spatial variables mentioned in the above paragraph. First of all, we make a distinction in our data between buildings with and without a communal space for socializing. In addition, we distinguish low-rise buildings (with a maximum of four floors) from high-rise buildings (with more than five floors). By crossing these two variables, four types of buildings within the housing stock of Woonzorg Nederland can be distinguished (N=411): 1. low-rise buildings without a communal space for socializing (35%), 2.

low-rise buildings with a communal space for socializing (40%), 3. high-rise buildings without a communal space for socializing (10%), and 4. high-rise buildings with a communal space for socializing (15%).

To gain more insight into these four building types, they are described based on relevant variables, such as the number of dwellings and the degree of vulnerability of the resident group, as perceived by the building manager concerned. In this study, vulnerability is defined as experiencing obstacles (of both a physical and mental nature) that make daily independent functioning difficult. Table 1 shows that resident groups that predominantly consist of vital seniors are overrepresented in buildings without a communal space for socializing. High-rise buildings with space for socializing are more often large-scale and relatively often have intramural units present. In general, high-rise buildings are more common in a (very) urban area than low-rise buildings. In the building type ‘low-rise buildings without a space for socializing’ (very) small-scale buildings are overrepresented.

Table 1. Descriptive characteristics of the residential building by building type (%).

	Low-rise buildings without space for socializing N=141	Low-rise buildings with space for socializing N=165	High-rise buildings without space for socializing N=42	High-rise buildings with space for socializing N=63	Total N=411
Distribution by vulnerability in the resident group					
Mostly vital residents	20%	7%	22%	6%	13%
A mix, but more vital than vulnerable residents	30%	31%	38%	44%	33%
About as many vulnerable as vital residents	21%	30%	19%	24%	25%
A mix, but more vulnerable than vital residents	23%	22%	19%	21%	22%
Mostly vulnerable residents	6%	10%	2%	5%	7%
Chi2 = 24,710*					
Degree of urbanity					
Non/little urban	30%	38%	17%	11%	29%
Moderately urban	23%	21%	2%	10%	18%
Highly urban	47%	41%	81%	79%	53%
Chi2 = 44,548***					
Number of dwellings in the building					
Very small-scale: 1-25 housing units	47%	27%	9%	5%	28%
Small-scale: 26-40 housing units	33%	23%	31%	6%	25%
Medium-scale: 41-80 housing units	19%	35%	50%	22%	29%
Large scale: 81-120 housing units	1%	11%	0%	29%	9%
Extra-large scale: > 120 housing units	0%	4%	10%	38%	9%
Chi2 = 182,686***					
Also intramural units present in the building	16%	9%	12%	29%	15%
Chi2 = 14,241**					
Activities organized in the building	21%	89%	19%	87%	58%
Chi2 = 192,298***					

Source: real estate data of housing association Woonzorg Nederland and survey data collected among their building managers. Own calculations. N = 411. χ^2-test for difference between housing types: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05.

2.3 Frequency and nature of contact among older residents

The frequency of contact with fellow residents was measured with the question "How often do you have contact with people living in your residential building?". Respondents could answer this question on a five-point scale, which we converted to three categories: 1. (almost) daily, 2. regularly (at least once a month, but not daily), and 3. (almost) never (less than once a month or never). These contacts can consist of personal encounters, contact by telephone or writing, and contact via e-mail, chat, app or text message. We were not only interested in the frequency of contact between residents, but also in the nature of this contact. This contact is labeled as 'friendly' (0-1) if, in addition to regular greeting or chatting, respondents indicate that they meet for coffee, have the keys to each other's house, and/or undertake social activities with other residents. Finally, personal characteristics that can relate to the willingness and/or ability to interact with neighbors, such as gender, age, educational level, and variables relating to respondents' vulnerability and social attitudes, were included as control variables. Table 2 shows the descriptive statistics of all variables included in the analysis.

Table 2. Descriptive statistics of the variables included in the analysis.

	%		%
Contact with fellow residents		*Background variables*	
Frequency of contact with other residents		Woman (0-1)	55.2%
(Almost) daily	47.0%	Educational level	
Regularly	38.9%	Lower educated	55.8%
(Almost) never	14.1%	Middle educated	23.2%
(Also) friendly contact with fellow residents (0-1)	45.9%	Higher educated	18.6%
		Other	2.4%
Indicators of vulnerability		*Social attitude and motivation*	
Age		Social considerations motivated the choice of housing (0-1)	22.9%
55-64 years	16.5%	Duration of residence	
65-74 years	28.5%	Less than 1 year	23.1%
75-84 years	32.2%	Between 2 and 7 years	50.0%
85 years and older	22.8%	More than 7 years	26.9%
(In)formal help with personal care and/or nursing (0-1)	14.6%	Having similar norms and values as fellow residents (0-1)	52.0%
Hindered by health problems in daily activities indoors and/or outdoors (0-1)	31.5%		
Living alone (0-1)	74.7%		**Mean**
Less than weekly contact with family and friends (0-1)	12.3%	Introversion - extroversion scale (0-12)	6.90
Struggle to make ends meet (0-1)	19.0%		

Source: Survey data collected among tenants (55+) in collaboration with housing association Woonzorg Nederland and research agency MAGIS Marketing & Research; own calculations. N=2,852.

3. Results and analysis

3.1 Building types and the frequency of neighborly contact

To be able to answer the research question of this paper, we examined the relation between the four building types and the frequency and nature of contact between older residents within their residential buildings. Figure 1 shows that older adults who live in low-rise buildings with a communal space for socializing have more frequent contact with other residents than older adults who live in one of the other building types.

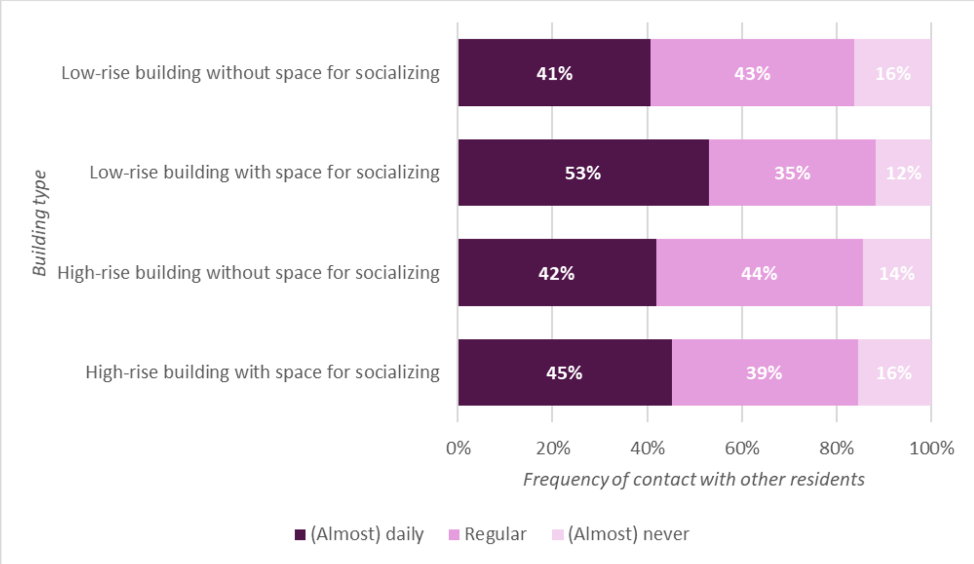


Figure 1. Frequency of contact with other residents by building type.

Source: Survey data collected among tenants (55+) in collaboration with housing association Woonzorg Nederland and research agency MAGIS Marketing & Research; own calculations. N=2,852. Chi^2 = 31.678***. χ^2-test for difference between housing types: *** = $p \leq 0.001$; ** = $p \leq 0.01$; * = $p \leq 0.05$.

To gain more insight into the relationship between building type and the frequency of neighborly contact, a nominal regression analysis was performed, based on 2,852 older residents. To minimize the risk of a spurious relationship, personal characteristics are included in the analysis that can relate to the willingness and/or ability to interact with neighbors.

Due to the ordinal nature of the dependent variable (frequency of neighborly contact), an ordinal regression analysis was first performed. However, the results of this analysis indicated that the predictors that determine whether or not someone has contact with fellow residents are different from the predictors that determine whether someone has regular or (almost) daily neighborly contact. Therefore, performing a multinomial logistic regression, in which the dependent variable *frequency of neighborly contact* is considered categorical, can be considered a good alternative. This analysis provides insight into the likelihood that residents (almost) never or (almost) daily have contact with fellow residents compared to the likelihood of having contact regularly (reference category). The results of this multinomial logistic regression are shown in table 3 and discussed in the next paragraph. In the analysis, dummy variables for the four building types in which the respondents live are included. In addition, we control for personal characteristics, such as background variables, indicators of vulnerability, and variables related to residents' social attitudes and motivation.

Table 3. Results of a multinomial logistic regression analysis of the frequency of contact with other residents (regular contact = reference category) by housing type, controlling for personal characteristics.

Frequency contact (Regular contact = ref.)	(Almost) never contact		(Almost) daily contact	
	Model a		Model b	
	B	SE	B	SE
Intercept	-.441	.283	-.429*	.212
Building types				
Low-rise buildings with space for socializing (ref.)				
Low-rise buildings without space for socializing	.034	.166	-.430***	.120
High-rise buildings with space for socializing	.131	.144	-.268**	.101
High-rise buildings without space for socializing	-.048	.213	-.495***	.151
Background variables				
Woman (0-1)	.095	.125	.001	.090
Educational level				
Lower educated (ref.)				
Middle educated	-.002	.146	-.234*	.106
Higher educated	.083	.161	-.164	.117
Other	-.116	.520	.389	.310
Indicators of vulnerability				
Age				
55-64 years (ref.)				
65-74 years	-.120	.165	.109	.124
75-84 years	-.210	.177	-.078	.134
85 years and older	-.584*	.243	-.062	.167
(In)formal help with personal care and/or nursing (0-1)	.454*	.197	-.153	.147
Hindered by health problems in daily activities indoors and/or outdoors (0-1)	-.142	.147	.108	.104
Living alone (0-1)	-.031	.152	-.446***	.102
Less than weekly contact with family and friends (0-1)	.827***	.152	-.228	.137
Struggle to make ends meet (0-1)	.192	.145	-.057	.109
Social attitude and motivation				
Social considerations motivated the choice of housing (0-1)	-.794***	.194	.413***	.105
Duration of residence				
Less than 1 year (ref.)				
Between 2 and 7 years	-.161	.141	.201	.105
More than 7 years	-.152	.172	.296*	.125
Having similar norms and values as fellow residents (0-1)	.057	.125	.154	.089
Introversion - extroversion scale (0-12)	-.076***	.019	.129***	.014
Nagelkerke pseudo R^2	.147		.147	

Source: survey data collected in collaboration with housing association Woonzorg Nederland and research agency MAGIS Marketing & Research; own calculations. N=2,852; b = regression coefficient; SE = standard error; *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05.

Model a (table 3) shows that building type is not significantly related to the odds of (almost) never engaging in contact with fellow residents rather than having contact regularly. Furthermore, model a provides more insight into the personal characteristics that relate to the odds of hardly having any contact with fellow residents rather than having contact regularly. For example, the findings show that the oldest group of residents (85 years and older) more often have regular contact with the residents in their residential building than the younger seniors (55-64 years). This is consistent with the picture that older seniors are more focused on the network in their immediate living environment, partly due to reduced mobility. In accordance with expectations, residents with a more introverted personality are more likely to have little or no contact with their fellow residents than residents with a more extroverted personality. Also, we observe that for residents who have less than weekly contact with family, friends and/or acquaintances the odds of rarely having contact with their fellow residents (compared to having regular contact) are more than twice as great as for residents who do have more than weekly contact with people outside the building (exp(.827)). Finally, model a demonstrates that the odds of not having neighborly contact instead of having regular contact are 57 percent higher for residents who receive at least weekly (in)formal assistance with personal nursing and/or care compared to those who do not receive this assistance (exp(.454)). These results indicate that residents who are socially or physically vulnerable are more likely to live isolated from their fellow residents. In the interviews conducted with residents, some also indicated that social or physical problems prevented them from making or maintaining contact with other residents.

> *"Yes, I have to say that now that I have this [pointing to her partly paralyzed face], I hold back a little. When I have just met people, I have a bit of a tendency to act like this [turned her face so it is less visible]. Yes, yes, I had to cross a barrier. Well, things have improved a bit now. But yes, I found that difficult."*
>
> *From an interview with a resident (age category: 55-64 years).*

> *"For example, they don't invite me either. They then have a drink together, three, four women and then... Yes, it makes sense that they do not invite me, because I mean, I can't stand that sound [respondent has hyperacusis and is hypersensitive to sound]. But that also feels like a rejection."*
>
> *From an interview with a resident (age category: 65-74 years).*

The results of the multinomial logistic regression analysis show a notably different scenario for the odds of having (almost) daily contact with neighbors instead of having neighborly contact regularly (table 3, model b). When controlling for the personal characteristics of respondents, we see that living in a low-rise building with a communal space for socializing (reference category) increases the likelihood of having (almost) daily contact with fellow residents. If we zoom in on the building types with a communal area for socializing, it turns out that the odds of having (almost) daily neighborly contact with fellow residents instead of regular contact are approximately 30 percent higher for residents living in low-rise buildings compared to those living in high-rise buildings (exp(.268)). The difference between the reference category and building types without such a space appears even greater. This is in line with interviews held with several residents of a low-rise complex with a communal area, which show that the organized activities that take place there can offer accessible opportunities to meet fellow residents.

"I drink coffee [organized in the communal space], not even every day. And for lunch, I always go downstairs [to the communal space]. Well, and there is always games night on Monday evening, from 7.00 to 8.30 pm, and I really enjoy it. I'm a person who loves games. And, we have a nice group of people. And yes, that is nice. Yes, I make grateful use of that. I really like it and we also have a very nice group of people that we play shuffleboard with."

From an interview with a resident (age category: 75 years and older).

Additional analyses show that the other three building types (apart from the reference category) do not differ significantly from each other regarding the likelihood that residents have (almost) daily contact with each other.

Furthermore, model b demonstrates which personal characteristics of residents are related to the likelihood of engaging more or less frequently with neighbors. Since it takes a while before getting settled and getting to know your neighbors, it is no surprise that the duration of residence influences the likelihood of having (almost) daily neighborly contact. We also see that for the residents for which social considerations played a role in the choice of the residential building the odds of having (almost) daily contact with fellow residents (relative to having regular contact) are 51% higher than for those who did not take social considerations into account (exp(.413)). Also, as expected, the model demonstrates that residents with a more extroverted personality are relatively more likely to have (almost) daily contact with other residents instead of regular contact. The model shows that with one step upwards on the introversion-extroversion scale (0-12), the odds of having (almost) daily contact with fellow residents instead of having regular contact increases by approximately 14% percent (exp(.129)). These results suggest that residents with a pro-social attitude who have taken social considerations into account in their housing choices are more likely to engage in having (almost) daily contact with their neighbors than those who have not.

3.2 Do older residents interact more friendly with each other in specific building types?

In this paper we are not only interested in the frequency of contact between residents, but also in the nature of this contact. Figure 2 illustrates the nature of neighborly contact for the group of respondents who have at least regular contact with their fellow residents (N=2,441). Just over half of this group has friendly contact with other people in the building, since they indicate that this contact includes meeting for coffee, having the keys to each other's houses, and/or undertaking social activities together.

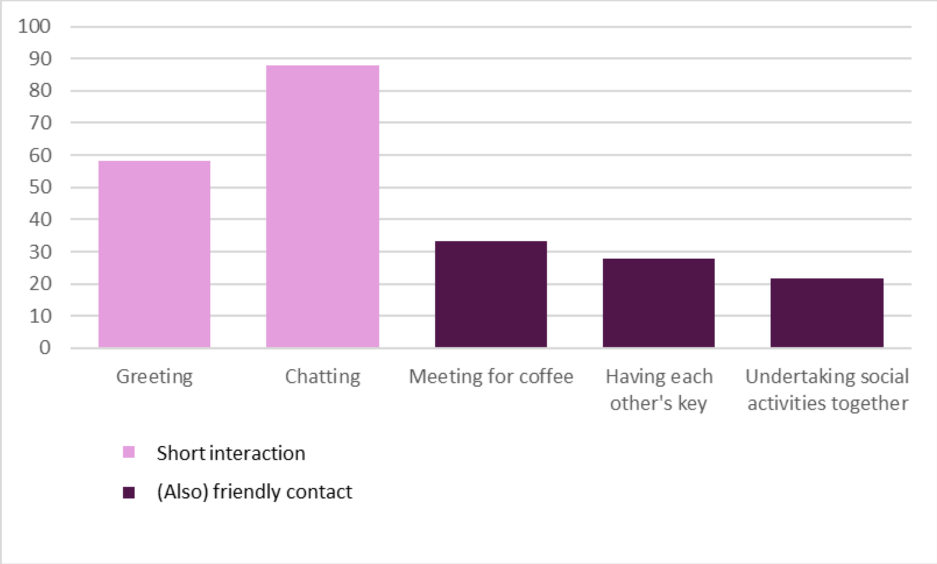


Figure 2. Nature of neighborly contact for the group of respondents who have at least regular contact with other residents of the building (in percentages).
Source: Survey data collected among tenants (55+) in collaboration with housing association Woonzorg Nederland and research agency MAGIS Marketing & Research; own calculations. N=2,441.

The question now is whether building type influences the nature of neighborly contact residents have, apart from its frequency. Figure 3 shows that 40 percent of residents of high-rise buildings without a communal space for socializing indicate that they (also) have friendly contact with fellow residents. This percentage is approximately 15 percent higher among residents of the other three building types. Whether this is attributable to the group size, the scale of the building and/or the absence of a communal space remains unanswered. However, interviews with residents revealed that living close to each other and jointly participating in organized activities in the communal space offer opportunities to strengthen social relationships with neighbors.

> *"Yes, those [good friendships] started here. If you move to a dwelling for independently living tenants of 55 years and older, then you don't actually realize that you are making use of the same door. And because you all go through one door, and of course, we also have [organized daily] coffee moments, it was very soon that, so to speak, friendship groups emerged. And, just like with an association, you can't be friends with everyone. But that actually selected itself. So that's very nice."*

From an interview with a resident (age category: 65-74 years).

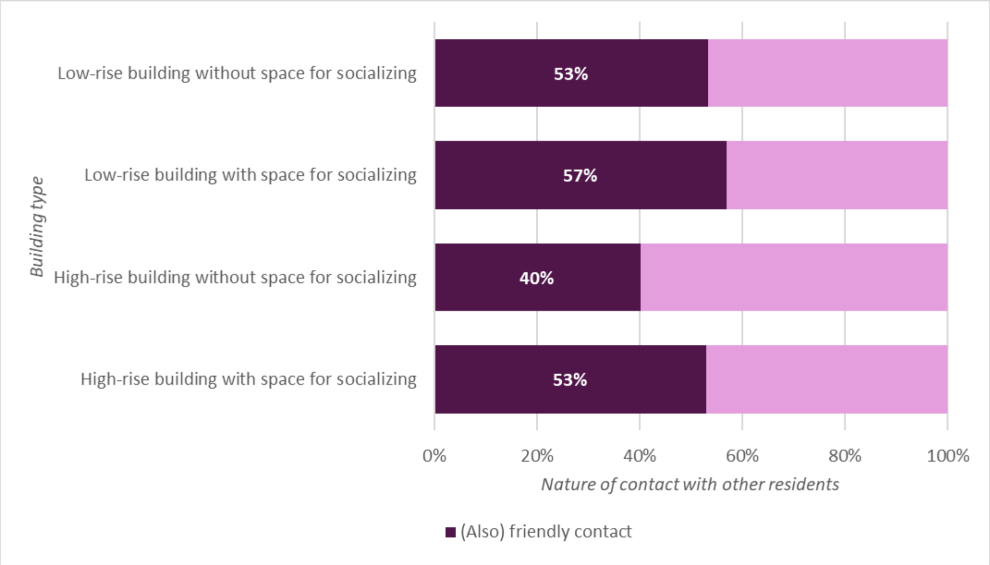


Figure 3. Nature of contact with other residents by building type, for the group of residents with at least regular neighborly contact.
Source: Survey data collected among tenants (55+) in collaboration with housing association Woonzorg Nederland and research agency MAGIS Marketing & Research; own calculations. N=2,441. Chi^2 = 17.762***. χ^2-test for difference between housing types: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05.

The findings of figure 3 are confirmed by the logistic regression analysis that was performed for the group of residents who have at least regular contact with other people in the building (table 4). In this analysis, we control for the personal characteristics of residents. The findings indicate that the odds of having friendly contact with fellow residents are between 40 and 45 percent lower for residents living in high-rise buildings without a communal space than for residents living in one of the other three building types. An additional analysis shows that these other three building types do not significantly differ from each other regarding the nature of neighborly contact. So while low-rise buildings with a communal space stand out positively when it comes to having (almost) daily contact, it is high-rise buildings without such a space that stand out negatively when it comes to having friendly contact.

Regarding the effects of personal characteristics, it appears that the odds of having friendly contact are 91 percent higher for women as compared to men (exp(.648)). Age appears to be positively related to the nature of contact; the likelihood of residents engaging in friendly interactions with fellow residents seems to increase with age. As in table 3, we see that the duration of residence, having a more extroverted personality, and having based the choice of housing on social considerations are positively related to contact. In this case the likelihood of having friendly contact.

Table 4. Results of a logistic regression analysis of the nature of contact with other residents by housing type, controlling for personal characteristics for the group of residents who have at least regular contact with other residents.

	(Also) friendly contact with fellow residents	
Nature of contact with fellow residents (0-1)	B	SE
Building types		
Low-rise buildings with space for socializing (ref.)		
Low-rise buildings without space for socializing	-.025	.121
High-rise buildings with space for socializing	-.089	.101
High-rise buildings without space for socializing	-.613***	.154
Background variables		
Woman (0-1)	.648***	.091
Educational level		
Lower educated (ref.)		
Middle educated	.125	.107
Higher educated	.337**	.120
Other	.516	.317
Indicators of vulnerability		
Age		
55-64 years (ref.)		
65-74 years	.247*	.125
75-84 years	.478***	.135
85 years and older	.569***	.170
(In)formal help with personal care and/or nursing (0-1)	-.152	.151
Hindered by health problems in daily activities indoors and/or outdoors (0-1)	.115	.105
Living alone (0-1)	.009	.101
Less than weekly contact with family and friends (0-1)	-.205	.140
Struggle to make ends meet (0-1)	.015	.110
Social attitude and motivation		
Social considerations motivated the choice of housing (0-1)	.730***	.106
Duration of residence		
Less than 1 year (ref.)		
Between 2 and 7 years	.541***	.107
More than 7 years	.707***	.127
Having similar norms and values as fellow residents (0-1)	.012	.090
Introversion - extroversion scale (0-12)	.072***	.014
Constant	-1.744***	0.220
Nagelkerke pseudo R^2	.120	

Source: survey data collected in collaboration with housing association Woonzorg Nederland and research agency MAGIS Marketing & Research; own calculations. N=2,441; b = regression coefficient; SE = standard error; *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05.

4. Discussion and conclusion

In this study, we examined whether four building types differ from each other in the frequency and nature of the contact between residents (55+). However, before discussing the findings of this study, we should also mention some limitations regarding the data collection that may have had a (limited) influence on the outcomes. One of the limitations is the time difference between the data collection among building managers and that among tenants of Woonzorg Nederland. The main data collection among building managers took place in 2020. However, due to COVID-19, data collection among tenants was postponed and carried out approximately two years later, in the summer of 2022. It may therefore be that adjustments have been made to the housing stock in the meantime, as a result of which in some cases the building-level characteristics in the data were no longer up to date when the residents' data were added. In addition, because the survey among residents was postponed due to COVID-19, the ongoing effects of this pandemic on contact (between residents) may have had a slight influence on the results. Another limitation concerns the context-specific nature of our findings. Although the data was collected at a housing association with national coverage in the Netherlands, it should be noted that this housing association focuses specifically on senior housing (55+). Although the way in which neighborly contact takes place may differ at other housing associations, with a different tenant population, it does provide an idea of the relationship between housing types and the frequency and nature of neighborhood contact.

Based on the findings of this study, we would like to discuss several insights. Firstly, building type does seem to influence the frequency and nature of neighborly contact for those who have at least regular contact with fellow residents. Residents of low-rise buildings with a communal space for socializing most often have (almost) daily contact with fellow residents, while residents of high-rise buildings without such a communal space least often (also) interact friendly with their neighbors. Therefore, we can conclude that communal spaces for socializing can promote organized encounters between residents, which can be of added value for residents who are willing and able to participate. However, there is also a group of residents who have (almost) never contact with fellow residents and who do not (can or want to) participate in organized activities. For some residents, this can be explained by a lack of interest in interacting with other residents. Others seem to encounter physical and/or social barriers when establishing or maintaining contact with fellow residents (Moor et al., 2023). In this specific group, socially more vulnerable residents seem to be overrepresented. These residents appear to benefit to a lesser extent from a residential environment that facilitates (organized) encounters. That is why housing associations and their partners need to gain more insight into which type of (social and spatial) interventions can have added value for which type of residents. For example, housing associations could consider designing residential environments that not only facilitate organized meetings, but also spontaneous encounters in which a broader audience can participate.

Secondly, it seems interesting to gain more insight into the *use* of the communal space for socializing by residents in different building types. For example, in small-scale low-rise buildings, contact is established more easily due to the small resident group, which may affect the relevance of a communal space for socializing in facilitating neighborly contact. In large-scale high-rise buildings, on the other hand, residents may experience a barrier when using the common area for socializing (on the ground floor) due to a larger (vertical) distance between their home and this space. More knowledge about how and where people meet in different building types and the role of communal spaces therein can help housing associations, among others, in developing suitable living environments for older tenants that support ageing in place.

Thirdly, based on the findings we can conclude that the two spatial characteristics of the building included in the analysis can influence the frequency and nature of neighborly contact. However, also social and organizational aspects of the residential environment, such as the composition of the resident group and the organization of the residential community, can influence contact between residents. In addition, the context-related features of the environment in which the building is located can also play a role in neighborly contact, such as the degree of urbanization. Therefore, when examining the potential of the residential environment for stimulating neighborly contact, spatial aspects of the residential environment cannot be seen separately from its social, organizational, and context-related characteristics. These factors will have to be taken into account integrally in further research.

Acknowledgements

This exploratory study is part of a collaborative project between HAN University of Applied Sciences, Eindhoven University of Technology and housing association Woonzorg Nederland. The data presented was collected in collaboration with Woonzorg Nederland and research agency MAGIS Marketing & Research. Our special thanks go to our colleagues at Woonzorg Nederland. Finally, we would like to thank all building managers and tenants of Woonzorg Nederland who have contributed to this research.

References

Cramm, J. M., Van Dijk, H. M., & Nieboer, A. P. (2013). The importance of neighborhood social cohesion and social capital for the well being of older adults in the community. *The Gerontologist*, 53(1), 142-152.

Doekhie, K. D., De Veer, A. J., Rademakers, J. J., Schellevis, F. G., & Francke, A. L. (2014). *Ouderen van de toekomst. Verschillen in de wensen en mogelijkheden voor wonen, welzijn en zorg, een overzichtsstudie (Elderly people of the future. Differences in the wishes and options for housing, welfare and care, an overview study)*. Nivel.

Glendinning, C., & Moran, N. (2009). *Reforming long-term care: recent lessons from other countries*. Social Policy Research Unit, University of York.

Grootegoed, E., & Van Dijk, D. (2012). The return of the family? Welfare state retrenchment and client autonomy in long-term care. *Journal of Social policy*, *41*(4), 677-694.

Kearns, A., Whitley, E., Mason, P., & Bond, L. (2012). 'Living the high life'? Residential, social and psychosocial outcomes for high-rise occupants in a deprived context. *Housing Studies*, 27(1), 97-126.

Ministry of the Interior and Kingdom Relations [Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2022). Nationale prestatieafspraken [National performance agreements]. Retrieved January 26, 2024, from Nationale prestatieafspraken 2022 | Publicatie | Home | Volkshuisvesting Nederland.

Ministry of the Interior and Kingdom Relations [Ministerie van Binnenlandse Zaken en Koninkrijksrelaties] (2023). Statistics based on CBS Microdata. Statistics available on the Datawonen portal of the Ministry of the Interior and Kingdom Relations of the Netherlands (BZK): https://55plus.datawonen.nl/dashboard/dashboard/ouderenhuisvesting (retrieved September 22, 2023).

Ministry of the Interior and Kingdom Relations [Ministerie van Binnenlandse Zaken en Koninkrijksrelaties] (2024). Regeling ontmoetingsruimten in ouderenhuisvesting [Regulations for spaces for encountering in senior housing]. Retrieved April 8, 2024, from https://www.volkshuisvestingnederland.nl/onderwerpen/regeling-ontmoetingsruimten-in-ouderenhuisvesting

Moor, N., Van Loon - van der Logt, M., Hamers, K., & Mohammadi, M. (2023). Grip op eenzaamheid en sociaal isolement in de sociale huursector. *Geron. Tijdschrift over ouder worden & samenleving 25* (4).

Thomese, G. C. F. (1998). *Buurtnetwerken van ouderen: Een sociaal-wetenschappelijk onderzoek onder zelfstandig wonende ouderen in Nederland (Neighborhood networks of the elderly: A social scientific study among independently living elderly people in the Netherlands)*.

Tyvimaa, T. (2011). Social and physical environments in senior communities: The Finnish experience. *International Journal of Housing Markets and Analysis*, 4(3), 197-209.

Williams, J. (2005). Designing neighbourhoods for social interaction: The case of cohousing. *Journal of Urban design*, 10(2), 195-227.

Wrzus, C., Hänel, M., Wagner, J., & Neyer, F. J. (2013). Social network changes and life events across the life span: a meta-analysis. *Psychological bulletin*, *139*(1), 53.

1 Empathic & caring living environment: **Conference paper**

Observable behavior and affective states of people with dementia during wayfinding: a pilot study in two nursing home corridors

Leonie van Buuren[1*], Daantje Derks[2], Masi Mohammadi[1]

[1] The Chair of the Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Erasmus University Rotterdam, The Netherlands

*Corresponding author: Leonie van Buuren (l.p.g.v.buuren@tue.nl)

Abstract: While wayfinding skills are crucial in autonomously conducting daily activities, it is a decreasing skill for people with dementia. Understanding how people with dementia find their way around and how they emotionally respond during this activity, especially at decision moments, can provide insights into more suitable nursing home designs. Six nursing home residents with severe dementia of two care organizations were given a wayfinding task. The executed tasks were observed and analyzed on wayfinding behaviors and affective states. The majority of the observed behaviors at decision moments were pronouncing aloud destinations or directions and help by carers providing verbal navigational cues. People with dementia might need confirmation at decision moments about their routes to reduce raised confusion. Mostly, neutral facial expressions were observed, which might physiologically be varied from stressful events to relaxing moments. These findings would imply increased confusion at decision moments during active wayfinding.

Keywords: Decision moments; wayfinding task; mood & agitation; wayfinding behavior

1. Introduction

Wayfinding is an essential skill in autonomous living (Andersen, et al., 2004). People continuously find their way, sometimes consciously (e.g., in exploring a new city) but often unconsciously (e.g., in your daily route from home to work or to the coffee corner from your desk in the office). However, people with dementia lose their wayfinding skills. While wayfinding refers to the dynamic processes including several steps along the way to, in the end, reach your destination, spatial orientation is knowing your current position in space (Passini, 1984). Wayfinding skills of people with dementia deteriorate because of e.g., a decline in their spatial orientation capabilities due to their dementia process (Reisberg, et al., 1982). Due to their dementia, this leads to fading away the conscious and unconscious manner of wayfinding, and even navigating a regular route can become challenging.

Automatic routes, for example, moving from the living room to the bedroom in a nursing home, in the end becomes a significant challenge. In the Netherlands, people with advanced dementia often live in nursing homes because independent living became impossible at a later stage (Den Draak, et al., 2016). While people with dementia already experience difficulties in wayfinding in the early stages of dementia (Pai & Jacobs, 2004), adapting to new situations, for example, finding your way around in a new building design, becomes an ordeal (Lawton & Simon, 1968). The spatial and interior designs of nursing homes in the Netherlands vary, from small-scale pavilions to large-scale buildings with endless corridors (van Liempd, et al., 2009). Nonetheless, each nursing home design has places in which decisions should be taken. These decision moments are locations in the building with a change in direction and where the user should decide left, right, or straight ahead, often shaped as a crossroad (Janzen, 2006; Veldkamp, et al., 2008). Making decisions becomes more difficult for people with dementia and some research argues that these spaces could be stressful for them (Marquardt, 2011).

Stressful situations could occur when you are unaware of where you are and are unable to discover a way to reach your destination. This could happen already to people with 'healthy' cognitive abilities. In stressful situations, people are aroused and anxious due to a situation which is unpreferred and unmanageable (Fink, 2016). People with dementia experience difficulty in spatially orienting themselves, creating a cognitive map of the space, and making decisions, which could result in stressful responses during wayfinding. Stressful responses – and affective responses in general – influence wayfinding processes; for example, the perception of space (Balaban, et al., 2017; Ruotolo, et al., 2019), attention (Balaban, et al., 2017), and making decisions (Delgrange, et al., 2020).

Wayfinding is considered by Passini (1984) as a spatial problem-solving process, including processing environmental information, development of plan, and executing the plan. Making decisions is an essential aspect of these iterative steps: in selecting relevant environmental information, developing a suitable route, and at a crossroad when executing the developed route. Related wayfinding behaviors are, for example, looking at while selecting relevant information, cognitive mapping (i.e., pronouncing aloud directions) while developing a plan, and stops on the route when executing the developed route (e.g., Rainville, et al., 2001; Mutsikawati, et al., 2021).

In the research of Van Buuren, et al. (under review), these wayfinding behavioral patterns were observed while people with dementia were just walking around in the nursing home; they were not actively asked to find a specific destination. Compared to the first type of behavior, active wayfinding behavior has a goal-oriented nature. During wayfinding, the wayfinder is actively searching for a specific destination, perhaps resulting in different behavioral patterns and affective responses.

1.1 The current study

While wayfinding is essential to maintain the quality of life of people with dementia (Andersen, et al., 2004), it is a decreasing skill (Reisberg, et al., 1982). Being unable to find your way and being lost, could cause feelings of stress (e.g., Delgrange, et al., 2020). It is important to realize that the nature of dementia entails that the cognitive skills that are key in finding your way, are affected already in an early stage of the condition. Unfortunately, there is no cure for Alzheimer's Disease yet and the condition is progressive and degenerative. However, we can change their living environment (nursing homes) which can contribute to their quality of life (Torrington, 2007). Architecture has the strength to support wayfinding skills for people with dementia. However, prior to changing the architecture of the living environment, it is crucial to understand the performed behaviors and affective states of people with severe dementia during wayfinding in these environments.

Building on the results of the study of Van Buuren, et al. (under review), we propose that highly visible crossroads contribute to wayfinding for cognitive 'healthy' people but may be confusing for people with dementia. The question arises of which wayfinding behavioral patterns can be identified at decision moments when conducting a wayfinding task. In combination with the hypothesis that affective states related to stress can occur at decision moments (as mentioned by Marquardt (2011)), the research question in this exploratory paper is: Which observable wayfinding behavioral patterns and affective states of people with dementia can be identified at decision moments in nursing home corridors while conducting a wayfinding task? To the best of our knowledge, this information is lacking in current literature.

2. Methods

To study the behaviors and affective states of people with advanced dementia in nursing homes during wayfinding, an exploratory observational study with wayfinding task was conducted. With this wayfinding task (e.g., McGilton, et al., 2003; Rainville, et al., 2001), six nursing home residents with advanced dementia (n=6) from to different nursing homes were asked to actively reach a given destination.

2.1 Procedure

The researcher approached the resident at a random spot in the collective living room or in the hallway, without the bedroom in a direct line of sight, and engaged in a conversation. The researcher asked if the resident could show her individual bedroom. During the wayfinding task, the researcher walked along the resident, slightly behind, to observe the behaviors and affective state. The researcher knew the location of the resident's bedroom. When the resident arrived at his/her bedroom, the wayfinding task ended. If the resident was unsuccessful in arriving at the destination and walked along her bedroom, the wayfinding task ended.

2.2 Data collection

A direct observation technique was used to observe the behaviors and affective states of the resident during the wayfinding task. Additionally, the wayfinding task was recorded by video from the perspective of the resident, to explore their point of view.

The following predefined wayfinding behavioral patterns were noted: looking at, cognitive mapping (i.e., pronouncing aloud direction), pronouncing aloud destination, travelled route, stops on the route, arrival at destination (e.g., Rainville, et al., 2001; Mutsikawati, et al., 2021).

Furthermore, two indicators of affective states were identified via observation: emotion and agitation levels. For both indicators, validated scales for people with dementia were used (Appendix). The OERS – Observed Emotion Rating Scale – uses six categories to identify emotion: pleasure, anger, anxiety/fear, sadness, interest, and contentment (Lawton, et al., 1996). The MEDLO – Maastricht Electronic Daily Life Observation Tool – scores agitation on a 5-point Likert scale, with zero as no agitation and four as extremely agitated (de Boer, et al., 2016). The researcher filled in the observational scales based on facial expressions, body gestures, tone of voice, and what participants said. The scales were reviewed by a peer during the study.

2.3 Data analysis

The notes and video footage of the wayfinding task were transcribed into a text file and in a graphic novel including the location on the map, visual image of the scene, wayfinding behavior, affective state, and quote of the resident. The behavioral mapping technique was used to annotate the behavioral patterns and affective states on the floorplan.

2.4 Context

The study was conducted in two psychogeriatric nursing homes of two different care organizations in the Netherlands (i.e., case study 1 and case study 2). Both nursing homes follow the same housing and care concept: a group of people with severe dementia lives together in a (closed) ward, with a shared living room with a kitchen and individual bedrooms. The floorplans of the wards of the nursing homes are displayed in Figure 1, indicating also the decision moments.

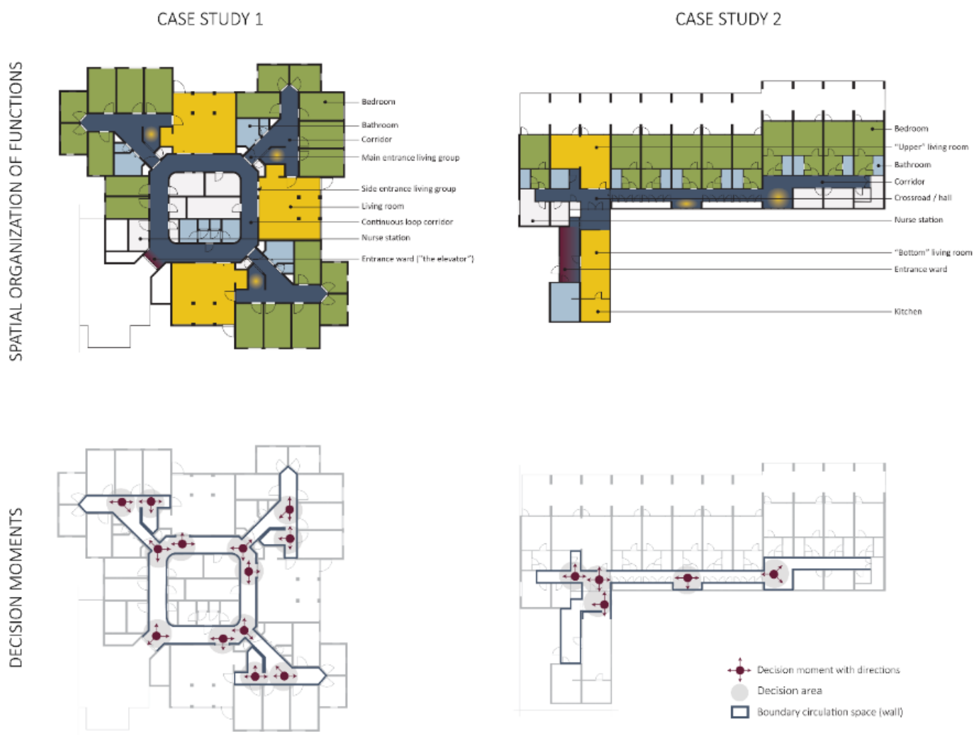


Figure 1. Floorplans of both case studies, including spatial analysis of spatial organization of functions and locations of decision areas

2.5 Sample

Six residents with severe dementia (i.e., Alzheimer's Disease and one resident with frontotemporal dementia (P1C)) (n=6) conducted the wayfinding task, three residents per nursing home. P1B (case study 1, resident B) performed the wayfinding task twice from different departure points, as control situation; resulting into seven performed wayfinding tasks. P1A used a walker during the search, P1B a walking stick, and P1C, P2A, P2B, and P2C did not use any walking aids during the task.

Informed consent for participation was given by the informal caregivers in consultation with the involved care organization. The set-up of the study was approved beforehand by the ethical review board of the Eindhoven University of Technology. On the spot, special attention was given to the consent of the residents: if the resident did not wat to conduct the task, he/she did not have to. However, all six residents agreed to conduct the task.

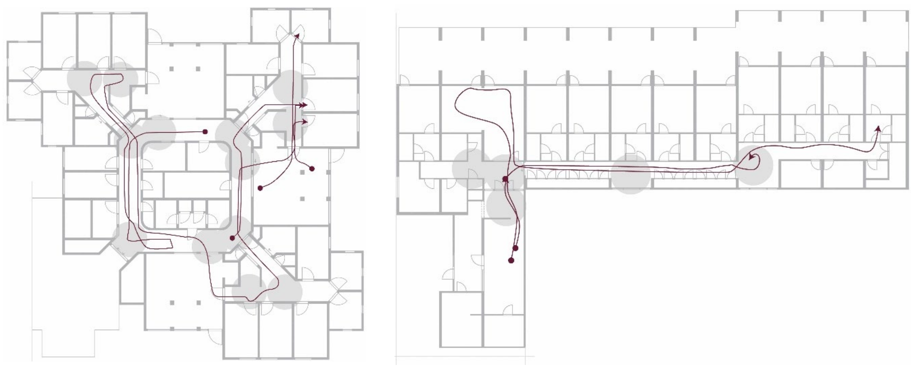
This study is part of a larger study in which daily (wayfinding behavioral) patterns (van Buuren, et al., under review) and the lived experience (Hammink, et al., under review) were measured in corridors and living rooms. However, the current study focuses on active wayfinding in the two nursing home wards.

3. Results

3.1 Performed wayfinding tasks

Seven routes were taken by the six residents. Figure 2 shows the travelled routes of the participants during the wayfinding task. In case study 1, all participants succeeded in completing the task, resulting in all participants arriving at the given destination and recognized this destination. All routes contained one or multiple decision moments. P1A walked to the 'right' position of the individual room but in the wrong living group corridor. This happened twice. However, with some help from care professionals at the 'wrong' positions, P1A succeeded in arriving at the destination.

Only one wayfinding task in case study 2 was successfully completed, though with a detour due to distraction (P2B). It seemed that P2A did not understand the task correctly, and P2C did not recognize her individual room. Both the routes of P2A and P2C stagnated at decision moments.



Case study 1 (n=4 routes)   Case study 2 (n=3 routes)

Legend: Circle = origin / starting point | arrow = ending point / destination; grey dot = decision area

Figure 2. Routes of wayfinding task

3.2 Wayfinding behavioral patterns

Figure 3 shows the wayfinding behavioral patterns annotated on the floorplans of the case studies. In both case studies, the wayfinding behavior looking at occurred often; participants looked at signs in the corridor. They pointed towards them or read them aloud during their search. In addition, care professionals provided guidance via verbal navigational cues in both case studies, especially to P1A and P2C.

In case study 1, wayfinding behavioral patterns were identified for the whole course of the routes taken; both on decision moments and other areas in the corridor. P1A showed the same behaviors at possible decision locations sequentially: (1) looking at, (2) pronouncing aloud a new destination or direction, and (3) moving accordingly (i.e., traveled route).

In case study 2, the wayfinding behavioral patterns seemed more clustered in the central hallway, near the window in the long corridor, and at the crossing near the experience spot in the corridor. These are decision moments in the floorplan.

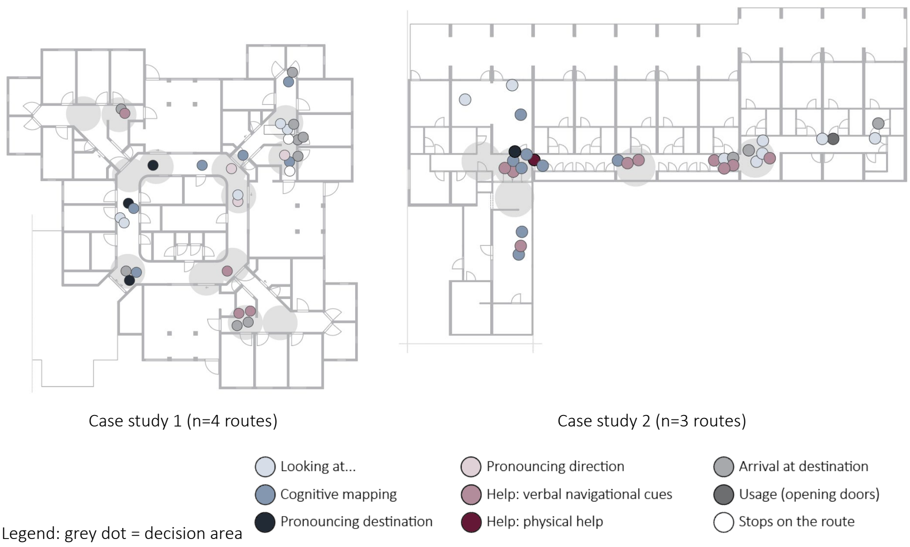


Figure 3. Wayfinding behavioral patterns observed during the performance-based orientation tasks plotted on the floorplans

3.3 Affective states

<u>Emotion.</u> In case study 1, almost all observed emotions of the participants over the entire route were positive (i.e., pleasure or interest) or contentment. In the search of P1A, a moment of anger and fear occurred when P1A failed to identify her own room for the second time (see Figure 4). Anger and fear/anxiety were observed by tone of voice's raise and looking back and forth.

In case study 2, participants showed a variety of emotions: pleasure, interest, contentment, and sadness. The sadness measurements belonged to participants P2A and P2C. Based on unstructured observations during the day of the measurements, they were in a sad mood the whole day.

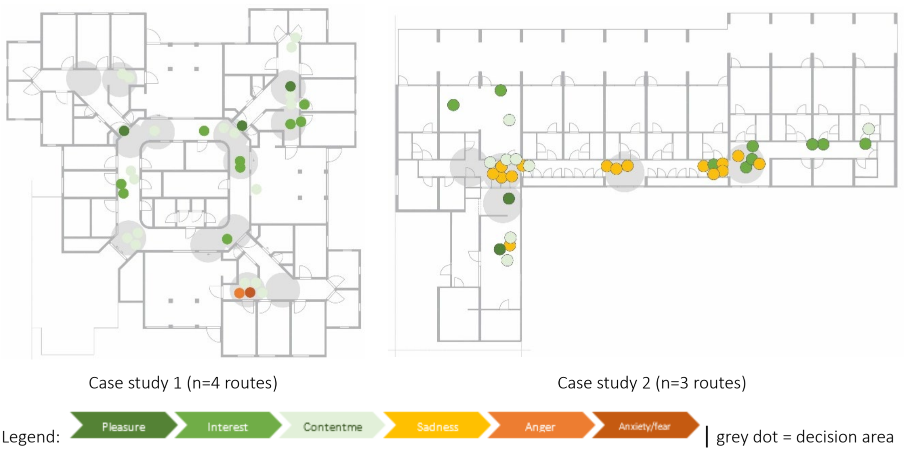


Figure 4. Observed moods at locations of wayfinding behavioral patterns annotated on the floor plans

Agitation. In both case studies, almost no agitation was observed during the performance-based orientation tasks (see Figure 5). Except for one moment of P1A, when she failed in arriving at her room for the second time.

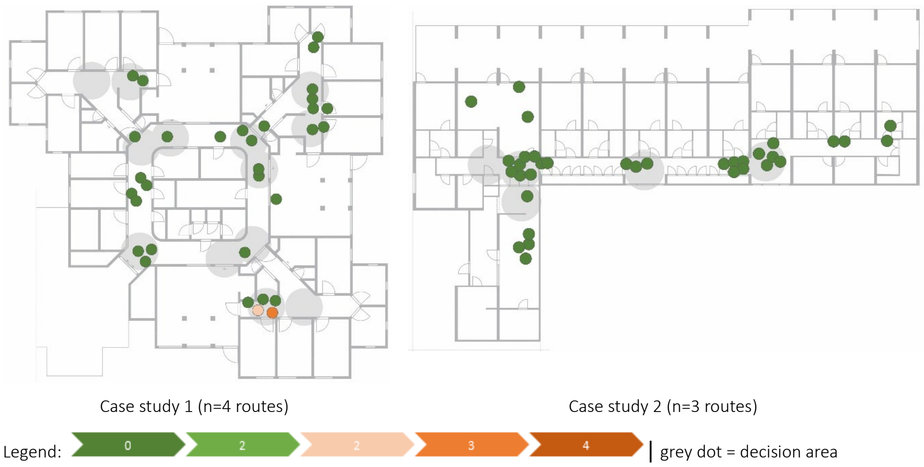


Figure 5. Observed agitation levels at locations of wayfinding behavioral patterns annotated on the floor plans

4. Discussion

Although wayfinding skills are decreasing for people with dementia, wayfinding is still essential to autonomously conduct daily activities to maintain their quality of life. Understanding how people find their way and how they emotionally respond during this activity, especially at decision moments, can ultimately provide insights to create a more suitable design for nursing homes. Therefore, this study aimed to identify which observable wayfinding behavioral patterns and affective states people with dementia exhibit at decision moments while wayfinding. Seven routes were undertaken by six nursing home residents in two case studies. In case study 1, all routes taken succeeded in arriving at the destination, while in case study 2, only one route was successful.

4.1 Wayfinding behavioral patterns at decision moments

In case study 2, the wayfinding behavioral patterns were more clustered surrounding the decision moments, while in case study 1, these behaviors were more scattered throughout the entire route. Most of the observed behaviors at decision moments were signals concerning cognitive mapping (i.e., pronouncing aloud destinations and directions), help by carers providing verbal navigational cues, and in case study 2, looking at (although prompted by a care professional). This might indicate that participants needed a spoken directional cue before deciding their next direction, either from themselves of by a care professional. These decision moments required some extra thinking from the residents. Possibly, it might suggest that the architecture of these spaces lack sufficient guidance to proceed the wayfinding task.

Knowledge about the overall architecture of the layout of the nursing home ward, is often captured in cognitive maps. Cognitive mapping is a decreasing skill for people with dementia in general (Passini, et al., 1998). However, although we cannot literally measure if the residents have drawn a cognitive map of the route in their minds, we can identify some indicators, such as pronouncing directions and destinations out loud. This was observed in the study (e.g., 'second door on the left'). This might indicate that some participants still try to develop a cognitive map, helping them to find their way around.

4.2 Affective states at decision moments

At decision moments, in almost all observations, signals of contentment mood without agitation were often observed in both case studies. Sometimes a sad emotion was observed, but this was also the baseline emotion of that particular resident. Only P1A showed some signs of anger, anxiety, and agitation. The question arises if these signs were built up during the route because she had some wrong 'arrivals'. However, the signs were relatively shortly observed, because after directions of a care professional, P1A showed signs of positive mood.

Based on this explorative study, we cannot describe the decision moments as stressful based on facial expressions and body language, as expected by Marquardt (2011). However, literature mentions innovative possibilities to measure affective states with wearable sensors (Bourne, et al., 2019; Kreiberg, et al., 2010). In the study of Hammink, et al. (under review), they observed that what happens inside – physiologically – while a contentment mood was observed varied from stressful events to relaxed moments. Therefore, we recommend to measure the affective states of people with dementia at decision moments both via observations and biometric sensors.

4.3 Limitations and recommendations for future research

The study encountered a couple of limitations. First is the limited sample size of six residents. It is always challenging to conduct empirical research with people with advanced stages of dementia due to ethical and practical reasons. The current study was an exploratory research to discover behaviors and affective states at decision moments. We recommend conducting research to a greater extent to gather more empirical data to develop a solid source of information about the behaviors and affective states of people with advanced stages of dementia during wayfinding. To ultimately provide knowledge on the designs of suitable living arrangements.

Second, although in our study familiar routes were evaluated, 'unfamiliar' routes in their living environment could be examined as well. While regular, familiar routes can become challenging due to dementia, this study showed that the majority of the wayfinding tasks were successfully completed. The routes from the living room to the individual bedroom are taken daily by the residents, sometime multiple times a day. However, more 'unfamiliar' routes, for example, from the collective living room to the restaurant of the nursing home, might require more cognitive capacities of the people with severe dementia, and could result into additional or other wayfinding behavioral patterns and affective states.

Lastly, a deep analysis of the architecture of the decision moments lacks in this paper. This lack was intentionally, since this paper focuses on the behaviors of the residents. However, architecture can influence people's behavior as well as affective states (Karol & Smith, 2019). Based on the literature, people with dementia can still develop a route if proper environmental information is provided (Passini, et al., 1995), but they can experience difficulties in selecting relevant information during the search due to dementia (e.g., Davis & Sikorskii, 2010; Kuliga, et al., 2021). Understanding these kind of mechanisms could provide valuable information about how to design suitable living spaces for this target group.

5. Conclusion

The observed wayfinding behavioral patterns and affective states at decision moments highlight that that confusion seems to increase for people with severe dementia at these decision moments during active wayfinding, just like during movement behavior in corridors (i.e., passive wayfinding) in the study of Van Buuren, et al. (under review). This explorative study showed that people with advanced dementia in nursing homes might need some confirmation about their routes at decision moments, either from themselves (i.e., pronouncing the direction aloud) or from carers (i.e., by verbal navigational cues). Decision moments on routes in nursing home designs can be confusing; also the more distraction displayed at these place, the more confusion could arise. It is at these places, that we saw many different objects in the case studies. Future studies should delve into the architecture of these decision moments and related behaviors and affective states to design sufficient nursing homes.

Acknowledgements

We would like to express our gratitude to the care organizations Oktober and Zorggroep Oude en Nieuwe Land for their warm welcome. In addition, we would like to thank Coosje Hammink MSc as a research partner. Together we are working on a larger study in which emotions of people with dementia are measured in nursing home corridors and living rooms. Data presented in this article is part of this collaboration.

References

Andersen, C. K., Wittrup-Jensen, K. U., Lolk, A., Andersen, K., & Kragh-Sørensen, P. (2004). Ability to perform activities of daily living is the main factor affecting quality of life in patients with dementia. *Health and quality of life outcomes, 2*(1), 1-7.

Balaban, C. Z., Karimpur, H., Röser, F., & Hamburger, K. (2017). Turn left where you felt unhappy: how affect influences landmark-based wayfinding. *Cognitive processing*, *18*(2), 135-144.

Bourne, P., Camic, P., Crutch, S., Hulbert, S., Firth, N., & Harding, E. (2019). Using psychological and physiological measures in arts-based activities in a community sample of people with a dementia and their caregivers: A feasibility and pilot study. *Journal of Aging Studies and Therapies*, *1*(1).

de Boer, B., Beerens, H. C., Zwakhalen, S. M. G., Tan, F. E. S., Hamers, J. P. H., & Verbeek, H. (2016). Daily lives of residents with dementia in nursing homes: Development of the Maastricht electronic daily life observation tool. *International Psychogeriatrics, 28*(8), 1333–1343.

Davis, R., & Sikorskii, A. (2020). Eye tracking analysis of visual cues during wayfinding in early stage Alzheimer's disease. *Dementia and geriatric cognitive disorders*, *49*(1), 91-97.

Delgrange, R., Burkhardt, J. M., & Gyselinck, V. (2020). Difficulties and Problem-Solving Strategies in Wayfinding Among Adults With Cognitive Disabilities: A Look at the Bigger Picture. *Frontiers in human neuroscience*, *14*, 46.

den Draak, M., Marangos, A. M., Plaisier, I., & de Klerk, M. (2016). *Wel thuis? Literatuurstudie naar factoren die zelfstandig wonen van mensen met beperkingen beïnvloeden. [Good at home? Literature study into factors influencing living independently for seniors with disabilities]*. Sociaal en Cultureel Planbureau.

Fink, G. (Ed.). (2016). *Stress: Concepts, Cognition, Emotion, and Behavior: Handbook of Stress Series*, Volume 1 (Vol. 1). Academic Press.

Hammink, J.H.W., van Buuren, L.P.G., Moor, J.A., Derks, D.A.J.A., & Mohammadi, M. (under review). Evolving dementia care: an explorative study on the lived experience of older adults living with dementia in nursing homes.

Janzen, G. (2006). Memory for object location and route direction in virtual large-scale space. *Quarterly journal of experimental psychology, 59*(3), 493-508.

Karol, E., & Smith, D. (2019). Impact of Design on Emotional, Psychological, or Social Well-Being for People With Cognitive Impairment. *HERD: Health Environments Research & Design Journal*, *12*(3), 220-232.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological psychology*, *84*(3), 394-421.

Kuliga, S., Berwig, M., & Roes, M. (2021). Wayfinding in people with Alzheimer's disease: Perspective taking and architectural cognition—A vision paper on future dementia care research opportunities. *Sustainability*, *13*(3), 1084.

Lawton, M. P., Van Haitsma, K., & Klapper, J. (1996). Observed affect in nursing home residents with Alzheimer's disease. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 51*(1), P3–P14.

Lawton, M. P., & Simon, B. (1968). The ecology of social relationships in housing for the elderly. *The Gerontologist, 8*(2), 108–115.

Marquardt, G. (2011). Wayfinding for people with dementia: a review of the role of architectural design. *HERD: Health Environments Research & Design Journal*, 4(2), 75-90.

McGilton, K.S., Rivera, T.M., Dawson, P. (2003). Can we help persons with dementia find their way in a new environment? Aging Ment. Health 7(5), 363–371.

Mustikawati, T., Yatmo, Y. A., & Atmodiwirjo, P. (2021). Tours and Maps Operations as Movement Mechanism in Indoor Wayfinding. *Int. J. Technol, 12*, 887-896.

Pai, M. C., & Jacobs, W. J. (2004). Topographical disorientation in community-residing patients with Alzheimer's disease. *International journal of geriatric psychiatry*, *19*(3), 250-255.

Passini, R. (1984). Wayfinding in architecture.

Passini, R., Rainville, C., Marchand, N., & Joanette, Y. (1995). Wayfinding in dementia of the Alzheimer type: planning abilities. Journal of clinical and experimental neuropsychology, 17(6), 820-832.

Passini, R., Rainville, C., Marchand, N., & Joanette, Y. (1998). Wayfinding and dementia: Some research findings and a new look at design. *Journal of Architectural and Planning Research*, 133-151.

Rainville, C., Passini, R., & Marchand, N. (2001). A multiple case study of wayfinding in dementia of the Alzheimer type: Decision making. *Aging, Neuropsychology, and Cognition*, *8*(1), 54-71.

Reisberg, B., Ferris, S. H., de Leon, M. J., & Crook, T. (1982). The Global Deterioration Scale for assessment of primary degenerative dementia. The American journal of psychiatry.

Ruotolo, F., Claessen, M. H. G., & van der Ham, I. J. M. (2019). Putting emotions in routes: the influence of emotionally laden landmarks on spatial memory. Psychological research, 83(5), 1083-1095.

van Buuren, L.P.G., Derks, D.A.J.A., Mohammadi, M., & Colenbrander, B.J.F. (under review). Explorative descriptions of wayfinding behavioral patterns of seniors with dementia in two nursing home corridors.

van Liempd, H. M. J. A, van Hoekstra, E. K., Huibers, L. S.,&Oel, C. J. (2009). *Evaluatieonderzoek naar de kwaliteit van de huisvesting van kleinschalige woonvormen voor ouderen met dementie.* [Evaluation research into the quality of the housing of small-scale housing for seniors with dementia]. Eindrapportage.

Veldkamp, D., Hagethorn, F., Kröse, B., & De Greef, P. (2008). The use of visual landmarks in a wayfinding system for elderly with beginning dementia. *Global Telemedicine and eHealth Updates: Knowledge Resources. Luxembourg: Luxexpo*, 48-51.

Appendix | Observational scales affective state

Observed Emotion Rating Scale (OERS) (Lawton, et al., 1996)

Category	Signs
Pleasure	Smile, laugh, stroking, touching with "approach" manner, nodding, singing, arm or hand outreach, open-arm gesture, eye crinkled
Anger	Clench teeth, grimace, shout, curse, berate, push, physical aggression or implied aggression, like fist shaking, pursed lips, eyes narrowed, knit brows/lowered
Anxiety/fear	Furrowed brow, motoric restlessness, repeated or agitated motions, facial expression of fear or worry, sigh, withdraw from other, tremor, tight facial muscles, calls repetitively, hand wringing, leg jiggling, eyes wide
Sadness	Cry, tears, moan, mouth turned down at corners, eyes/head down turned and face expressionless, wiping eyes, horse-shoe on forehead
Interest	Eyes follow object, intent fixation on object or person, visual scanning, facial, motoric or verbal feedback to other, eye contact maintained, body or vocal response to music, wide angle subtended by gaze, turn body or move toward person or object
Contentment	Comfortable posture, sitting or lying down, smooth facial muscles, lack of tension in limbs, neck, slow movements

Maastricht Electronic Daily Life Observation Tool (MEDLO) (de Boer, et al., 2016).

	Deviating verbal expressions	Motoric agitation	Aggressiveness	Resistance to care (professional)
0	Not present	Not present	Not present	Not present
1	Low volume, not disruptive in milieu, including crying	Pacing or moving about in chair at normal rate (appears to be seeking comfort, looking for spouse, purposeless movements)	Verbal threats	Procrastination or avoidance
2	Louder than conversational, mildly disruptive, redirectable	Increased rate of movements, mildly intrusive, easily redirectable	Threatening gestures; no attempt to strike	Verbal/ gesture of refusal
3	Loud, disruptive, difficult to redirect	Rapid movements, moderately intrusive or disruptive, difficult to redirect	Physical toward property	Pushing away to avoid task
4	Extremely loud screaming or yelling, highly disruptive, unable to redirect	Intense movements, extremely intrusive or disruptive, not redirectable verbally	Physical toward self or others	Striking out at caregiver

1 Empathic & caring living environment: **Conference paper**

Farmyard Sharing Initiatives in the Netherlands: a state of the art

Nienke Moor[1]*, Moniek van Loon-van der Logt[1], Korrie Melis[2], Kim Hamers[1,3], Masi Mohammadi[1,3]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[1] Research Group Sociale Duurzame Praktijken, HAN University of Applied Sciences, The Netherlands

[3] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

* Corresponding author: Nienke Moor (nienke.moor@han.nl)

Abstract: This exploratory study maps the current situation of various Farmyard Sharing Initiatives (FSIs) in the Netherlands, which have been realized or are still being developed. Based on their spatial and social-organizational characteristics, collected through online desk research and additional contact with initiators, we distinguish three types of FSIs, each of which has a different focus and appears to serve a different target group. Based on individual discussions and an online focus group with stakeholders, we explore the possible benefits and obstacles of these three types FSIs in the context of rural development and developments in the housing market.

Keywords: Farm yard sharing; housing typologies; rural development; communal housing

1. Farmyard Sharing Initiatives

In the Netherlands, many farmers are ceasing their agricultural activities (CBS, statline), partly due to the policy aimed at nitrogen reduction and the shrinking of the livestock, and this number is expected to increase in the coming years. The agricultural real estate that has become available in this way and will become available in the near future, must be given a new purpose that meets the specific needs of the countryside and its residents. One of the options is to repurpose the vacant farmyard into a housing concept with space for several households: farmyard Sharing Initiatives (FSIs) (Stinkens et al., 2022).

When writing about FSIs in the (grey) literature, several characteristic elements are reflected. It always seems to concern a farmyard where the main farm building has been retained and has been given a residential function. In addition, several residential units are built on the plot which provide living space for a number of independently living households. The residents share (part of) the yard and garden, and in several cases also a (number of) interior space(s), such as a recreation room or spaces for more practical use. Although the extent varies per project, the emphasis is on a form of solidarity between residents, and special attention is regularly paid to sustainable living.

1.1 FSIs in relation to rural issues

The housing concept of farmyard sharing could relate to the problems currently occurring in rural areas (Hasselman et al., 2024), including double aging, population decline, declining facilities, and housing issues. FSIs can potentially provide suitable housing, especially to young people and older people from smaller villages who are looking for affordable housing in their region of origin. In this respect, FSIs may have the potential to attract or retain young people to smaller villages and offer seniors in these villages the opportunity to grow old in a rural environment with the help of their fellow residents.

Although sharing a farmyard can be an attractive housing solution for several target groups, it seems to be a particularly appropriate initiative in the context of an aging population and increasing isolation and/or loneliness among older adults. This housing concept offers older adults the opportunity to settle on a farmyard with like-minded people, making social interaction and informal care possible in a peaceful and beautiful environment. An exploratory survey conducted by the initiator of Erfdelen.nl among interested parties (who visited the website and made contact, N = 650) shows that approximately two-third of respondents are over fifty years old and just over forty percent live alone. The respondents indicated that in addition to the natural environment, privacy, and sustainable living, great value was also attached to the proximity of facilities and the possibility of informal care within this housing concept (Erfdelen.nl).

Farmyard sharing can also be part of rural development, as it provides a destination for former agricultural real estate, in such a way that the rural and agricultural identity of the living environment is not affected and environmentally harmful materials, such as asbestos, are removed from agricultural buildings (Koreman & Korthals Altes, 2023). Maintaining traditional and characteristic farms in the countryside has a high symbolic value in the context of preserving rural identity. Within FSIs, the farm can be kept intact for habitation or shared use by the residents, and the residential units that are added are often realized in matching architecture. However, it should be noted that the preservation of agricultural real estate is mainly a matter of preserving the exterior of farm buildings, and not so much of preserving the characteristic layout and details on the inside (Van der Vaart, 2005). Moreover, it is stated that FSIs located in rural areas, further away from the village center, may also negatively affect rural development, as these initiatives can hinder local anti-sprawl policies and could contribute to more traffic in the countryside (Jaarsma & de Vries, 2013; Koreman & Altes, 2023).

1.2 The current status of FSIs in the Netherlands?

In recent years, the concept of FSIs in The Netherlands has been addressed in grey and scientific literature. Several studies do not specifically focus on FSIs, but are more interested in the general state and (future) destination of vacant agricultural real estate (Gies et al., 2016; Gies & Smidt., 2020). Other studies zoom in on the housing concept of FSIs. For example, Langers (2024) discusses the opportunities of FSIs for societal issues in rural areas and the (procedural) barriers that different stakeholders, such as initiators and the municipality, are facing. Also, attention has been given to the role of provinces and municipalities in supporting new initiatives to develop and realize their plans.

In addition to the opportunities that FSIs offer, these studies mainly focus on the practical and financial feasibility of the broader housing concept. Particularly in relation to the process from making plans to actual realization, in which various stakeholders are involved. However, less is known about what characterizes the current FSIs and the possible variation that is reflected in them. This exploratory study therefore focuses more on the characteristic elements of FSIs and attempts to establish a relationship between the (variants) of this housing concept and social and demographic developments (in the housing market). Therefore, this article addresses the following research questions: a. Which types of FSIs can be distinguished based on their spatial and socio-organizational features? And b. What opportunities and limitations are associated with (these types of) FSIs in relation to current developments (in rural areas)?

2. Methods

2.1 Mapping and categorizing Farmyard Sharing Initiatives

In this exploratory study, we first mapped existing FSIs in the Netherlands, both those that have already been realized and those that are currently under development. We have selected projects where a) the original farm has been preserved, b) residents live independently and c) a part of outdoor and/or indoor spaces are shared. Without pretending to have an exhaustive overview of all these projects, we have tried to make the overview as complete as possible based on desk research, a list of projects shared by the initiator of www.erfdelen.nl, and snowball sampling. This (online) search ultimately resulted in an overview of twenty-two FSIs that we included in our analysis, of which information regarding spatial characteristics was also available for fifteen projects[1].

To gain a better insight into the characteristics of the FSIs in our overview and the variation that may or may not exist, we collected information about characteristics of the spatial design of the farmyard and the architecture used, the size of the resident group, the composition of the

[1] The list of included projects in this exploration can be requested from the authors.

resident group according to, among other things, age, household composition and region of origin, how residents (want to) organize themselves, and the relationship that exists or is desired with villagers from outside the settlement. We have also found information about the rental and/or purchase prices of the individual residential units for most projects (in a few cases an estimation was made by using purchase prices from the past). Where we found the most information on the website of the projects in question, in some cases we obtained additional information by emailing or calling initiators and/or residents.

After completing our overview, we attempted to categorize the projects based on existing combinations of spatial and socio-organizational variables in our dataset. First, we identified the most relevant variables in forming categories, which are the price range of the residential units, the location of the plot, the spatial layout of the housing concept, and the composition of the resident group. Where two researchers made an initial classification based on the characteristics of the FSIs, this was verified a day later by two other researchers and adjusted in certain respects. In both cases, one of them has a spatial background while the other researcher has a social background. This resulted in three types of FSIs, with their associated descriptions.

2.2 The perspective of different stakeholders

Prior to analyzing and categorizing existing FSIs, (online) exploratory discussions were held with various stakeholders to get an initial idea of the prevailing expectations about this form of housing from different perspectives. We first spoke to (1) the initiator of Erfdelen.nl, who provided us with information about the status quo regarding FSIs. In addition, we also spoke to (2) a professional in collective housing initiatives in the social rental sector, and (3) a policymaker from a rural municipality who is involved in spatial planning.

Also, after making the categorization of FSIs, we reflected on the three distinct types in an online focus group. We presented our results so far and discussed them for review and verification. Participants in this focus group were the professionals we had spoken to earlier (1-3), as well as (4) a professor in environment-inclusive entrepreneurship from an University of Applied Sciences. After this online focus group, the three types of initiatives were also presented for review and feedback to (5) a process supervisor (and also a resident) of Collective Private Commissioning projects and other cohousing initiatives (including FSIs).

3. Results and analysis

To answer our research questions, we first looked at the characteristics of the FSIs in our dataset and searched for patterns. As a result, we distinguished three types of FSIs, each of which is characterized by its own social-organizational and spatial characteristics. A brief description of each type in section 3.1 provides insight into the current state of affairs regarding FSIs in the Netherlands. In section 3.2 we will then discuss the (possible) connection of these distinct types of FSIs to rural development and housing issues in a more general sense, based on the discussions we have had with various stakeholders.

3.1 Three different types of FSIs

First, we would like to provide a more general picture of the FSIs we looked at. What is immediately noticeable is that most of the FSIs are still in development: almost completed, or have only just started. Nine initiatives have already been realized and are being occupied. Sociocracy, a non-hierarchical decision-making method, is regularly used in FSIs where residents interact more intensively with each other. In most initiatives, in addition to outdoor space, residents also share indoor spaces. Many FSIs have a communal space for socializing. Sometimes more functional spaces also are shared, such as a laundry and drying room, a hobby room, or a guest room. In the next paragraphs, the three types of FSIs that we distinguish in our database are described based on their social-organizational and spatial characteristics.

The first type of FSIs **'Making a Difference Together'** is characterized by the *shared ideological vision* of its residents, who consciously choose to form a residential community together and commit themselves to mutual responsibilities and corresponding agreements. Solidarity is strongly emphasized. In addition, it appears that in various communities within this type, there is a strong emphasis on sustainable and ecologically responsible living. With this type, we (also) see larger resident groups compared to other initiatives. A conscious choice has often been made for a *mixed composition of residents* based on age and household situation. The housing initiatives that belong to this type are *relatively affordable* compared to the other FSIs and consist not only of (mid-price) owner-occupied homes, but occasionally (also) of rental properties. From a spatial point of view, the communal character of this type is *reflected in the spatial configuration of the buildings and the presence of shared spaces*. The buildings often are situated around a centrally shared outdoor space that provides access to individual homes. In addition to the (sometimes) smaller residential units, residents share various indoor living spaces and facilities.

Figure 1. Illustration of Type I 'Making a Difference Together'. Designed by Kalle Wolters.

The second type of FSIs '**Grow Old Together**' is characterized mainly by the composition of its resident group by age and stage of life. Older adults within this type have selected a nice location, often *close to or just outside the village center*, where they can *grow old happily together with other (like-minded) seniors*. Residents in these FSIs have the intention to look out for each other and to help one another when necessary. This type mostly consists of *owner-occupied homes in the middle or high-price segment*. From a spatial point of view, this type seems less recognizable compared to the other two types of FSIs, because the projects seem to vary in terms of their scale and spatial configuration. However, many projects within this type have, in addition to private residential units with a garden, also *shared indoor and outdoor space(s) intended for socializing*.

Figure 2. Illustration of Type II 'Grow Old Together'. Designed by Kalle Wolters.

The third and last type of FSIs '**Enjoying and preserving the countryside**' seems to focus on the *preservation of heritage*, such as landscape design or characteristic farms, rather than on building a community of like-minded residents. The *desire to live in a beautiful and green environment* seems to be one of the most important considerations for residents of this type to live here. From the estate on which the initiative is located, these initiatives provide a steady source of income and at the same time an opportunity to preserve characteristic agricultural real estate and the associated landscape. FSIs belonging to this type are relatively often small-scale in nature and consist mostly of *owner-occupied homes in the higher price segment*. The importance of maintaining everyone's *privacy is reflected in the spatial configuration*; the houses are oriented more outwards and in most cases there are no shared indoor spaces present.

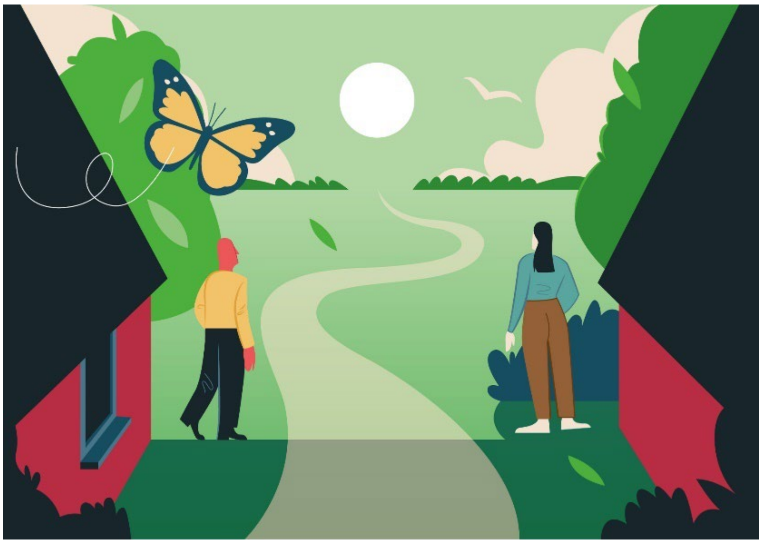


Figure 3. Illustration of Type III 'Enjoying and Preserving the Countryside'. Designed by Kalle Wolters.

3.2 A different perspective on Farmyard sharing initiatives

The three types of FSIs that were distinguished, were recognized by the various stakeholders with whom individual discussions were conducted and/or a focus group was held (see also paragraph 2.2). However, depending on their professional role, stakeholders seemed to pay more attention to and/or attribute value to a particular type. Broadly speaking, the discussions that were held with the various stakeholders can be traced back to four themes regarding (types of) FSIs.

First of all, the discussions revealed that the possible added value of (types of) FSIs depended on the perspective from which the stakeholders viewed these projects. When FSIs were considered from the perspective of housing problems in rural areas, their potential was particularly emphasized in the context of affordable housing supply in small villages, especially for young people and older adults. From the municipality's perspective, an important goal is to provide affordable (and sometimes temporary) housing to young people and seniors who want to continue living in their village of origin. An ideological basis or underlying solidarity seems less important (and also less possible). The policymaker from the rural municipality expressed her concern that a residential group with a strong ideological basis for solidarity and sustainable living would not fit well into the culture of rural residents with slightly different norms and values in this area. Stakeholders who viewed the FSIs from a more ideological perspective emphasized the added value of this form of housing for entering into more friendly (and also more long-term) (residential) relationships that could result in a higher degree of neighborly support. However, we see that these types of (relatively affordable initiatives), reflected in type I 'Making a Difference Together', are often initiated by a group of residents without prior local ties. Both perspectives on FSIs, from a more ideological or a more practical perspective, do not seem to fit well together when considering the possible added value of FSIs in rural areas.

Another point that emerged in our discussions with stakeholders was the importance they attached to the affordability of FSIs. From the municipality’s perspective, it was emphasized that FSIs may offer an affordable option, especially for younger people, to continue living in their village or region. However, stakeholders who are more involved in the realization of FSIs emphasized that the affordability of this form of housing is often overestimated. Making this form of housing affordable appears to be very difficult to achieve in practice and the form of housing also appears to be financially quite unattractive for housing associations due to its relatively small scale and isolated location. One stakeholder noted that smaller and more affordable residential units in such projects are often only possible if there are also larger and more expensive homes that can financially support the project. An important question that was asked is whether other financing models should be made possible which could make FSIs more feasible and more widely accessible.

A third point reflected in the individual discussions and the focus group is the question of how much value can be attached to the focus on solidarity between residents in certain types of FSIs. Particularly in initiatives with a strong ideological approach or with an emphasis on growing older together (types I and II), the question may be asked how sustainable solidarity is over time. For example, what happens if people develop (more serious) health problems, have disagreements about the management of their community, or move? Because relatively few projects have been completed, these questions remain unanswered for now. However, some stakeholders emphasize how important it is to properly secure underlying agreements in advance (statutes of owners' association) regarding, for example, balloting, renting out/selling the home, and adapting the architecture.

A final point that was discussed extensively is the opportunities but also the limitations that FSIs entail for the protection and maintenance of the rural area and the associated rural identity. The third type ('Enjoying and Preserving the Countryside') in particular was seen by some stakeholders as a good option for people with more financial options to live in a nice place outside, in the vicinity of others. One municipal employee made it clear that there are concerns about the protection of rural areas if residential areas are created outside the village center, also because this can lead to increased traffic and less efficient use of healthcare services. An important question therefore is how we can safeguard ecological values within this type of FSIs. And what can we expect in this respect from the residents of this housing initiative? The professor in environment-inclusive entrepreneurship emphasized that it is important for a municipality to establish preconditions in advance for the realization of an FSI concerning architecture and landscape design. In this light, it was also mentioned that asking for a (financial) contribution from residents to maintain or improve the quality of the rural area should be a realistic option.

4. Discussion and conclusion

In this explorative study, we have outlined the status quo regarding FSIs in the Netherlands. Without pretending to be able to provide a complete overview, we have looked at the characteristics of 22 FSIs, both those that have been completed and those that are still in development. In addition to important common denominators, such as the re-use of vacant agricultural real estate and the time-intensive and often difficult process from development to completion, we also see major differences between the various projects in terms of objectives and intended target group. This is reflected in the spatial and social-organizational features of the FSIs and how these features coincide with each other in practice (Moor & Mohammadi, 2020).

In the first type ‘Making a Difference Together’, the social layer of housing is central. In this type, residents often consciously choose to live together in a residential community and share the responsibilities that come with this. In addition to a strong focus on solidarity, attention is often paid to ecologically conscious living. Although this type certainly does not include low-cost housing, it does appear to be the most affordable type of Farmyard sharing, which includes both owner-occupied and rental properties in the private sector. It seems that solidarity and neighborly support are highly valued in this type, but there does not necessarily seem to be a local connection with the precise location of the project. However, vacant agricultural real estate does offer groups of ideologically oriented people an opportunity for suitable housing. This type therefore fits in with the national trend towards more collective housing with an emphasis on building neighborly connections, but appears to be less in line with the need for affordable housing for starters on the housing market looking for a suitable place to live in their region of origin.

The second type ‘Grow Old Together’ is somewhat similar to the first type in the sense that solidarity and neighborly support are highly valued. However, this type houses a homogeneous group of residents by age, unlike the first type. People consciously choose to grow old together and have the (financial) resources and skills to achieve this with the residents’ group and possibly some external guidance. In this housing type, the care-related layer of housing receives or should receive more attention than in the other two types of FSIs. The initiatives within this type are often located within or close to built-up areas, so that facilities remain accessible. Nevertheless, it seems sensible to think about the (digital) accessibility of healthcare services and smart innovations so that there is no excessive pressure on solidarity within the group of residents.

The third type ‘Enjoying and preserving the countryside' is not a solution to the search for more affordable housing for starters and seniors in the villages, but offers a nice option for people with sufficient financial resources to live outside in the vicinity of others, but while retaining privacy. This type is directly related to the preservation of estates and characteristic agricultural real estate. However, there needs to be more clarity here, also from the municipality, about what can be expected of residents (financially and practically) when it comes to the historical and ecological preservation of the rural area.

In addition to the discussion about the financial and procedural feasibility of FSIs, there is also a more substantive discussion about the relevance of this form of housing in the context of rural development and Dutch housing market trends. The exploratory results of this study will hopefully contribute to making this discussion (in both science and practice) easier and more transparent, as it provides insight into the fact that there are different types of FSIs, each of which has a different focus and appears to serve a different target group. The discussion about the added value of FSIs between stakeholders, such as policymakers in rural areas, collective housing initiatives (of both citizens and professionals from housing associations), and local residents, can be conducted better if it is clear to all involved what type of housing is being discussed in what context and for which target group.

Acknowledgements

Our special thanks go to Pieter Parmentier (initiator of www.erfdelen.nl) for the knowledge he brought to the project. Also, we would like to thank all professionals and residents who have contributed to the data collection underlying this study. This explorative study has been financed by the Fair Health program of the HAN University of Applied Sciences.

References

CBS, Statline. Agriculture; from 1851. https://www.cbs.nl/nl-nl/cijfers/detail/71904ned. Website consulted April 23, 2024.

Gies, T.J.A., Nieuwenhuizen, W., Naeff, H.S.D., Vleemingh, I., Paulissen, M. (2016). Landelijk gebied en Leegstand. Aard, omvang en oplossingsrichtingen van huidige en toekomstige leegstand agrarisch vastgoed in Nederland [Rural area and Vacancy. Nature, size and solutions of current and future vacant agricultural real estate in the Netherlands] (No. 2755). Wageningen, Wageningen Environmental Research.

Gies, T.J.A., Smidt, R. (2020). Inventarisatie leegstand agrarisch vastgoed Overijssel. Ontwikkeling, aard en omvang agrarisch vastgoed in provincie Overijssel tussen 2012 en 2018 en prognose ontwikkeling tot 2030 [Inventory of vacant agricultural real estate in Overijssel. Development, nature and size of agricultural real estate in the province of Overijssel between 2012 and 2018 and forecast development until 2030] (No. 2992). Wageningen, Wageningen Environmental Research.

Hasselman, S., Brouwer, J., Leemkolk, W. van de, Handgraaf, S., Mentink, M., Meijer, R. & Dankers, B. (2024). Handreiking Planologische concepten erftransformaties [Guidelines for Planning Concepts for Farmyard Transformations]. FLO Legal & Field Design & Development. Commissioned by the Ministry of Agriculture, Nature and Food Quality, The Netherlands.

Jaarsma, R. F., & de Vries, J. R. (2013). Former Farm Buildings Reused as Rural Villa, Building Contractor or Garden Centre: Consequences for Traffic Flows on Minor Rural Roads in a Changing Countryside. European Countryside, 5(1), 38-51.

Koreman, M. C. J., & Korthals Altes, W. K. (2023). Re-using vacant farm buildings for commercial purposes: Two cases from the Netherlands. Land Use Policy, 132, Article 106823.

Langers, F. (2024). Erfdelen: Nieuwe woonvormen op (voormalige) boerenerven. Onderzoek naar de kansen en knelpunten bij de realisatie van het concept erfdelen [Farmyard sharing initiatives: New housing concepts on (former) farmyards. Research into the opportunities and obstacles in the realization of the concept of farmyard sharing initiatives] (Rapport nr. 398) Wageningen University & Research, Wetenschapswinkel.

Moor, N. & Mohammadi, M. Grey Smart Societies: Supporting the Social Inclusion of Older Adults by Smart Spatial Design. In: Data-Driven Multivalence in the Built Environment, Biloria, N., Ed. Springer International Publishing: Cham, Switzerland, 2020; pp. 157–180.

Stinkens, C., Valentijn, R., Til, L. van, Trago, B., Schreuder, B., Margiotta, L., Liang, M., Versluijs, N. (2022). Unlocking the housing potential of farmyards. Overcoming the obstacles between initiators and municipalities within a farmyard sharing proposal. ACT (WUR), commissioned by de Wetenschapswinkel.

Van der Vaart, J. H. (2005). Towards a new rural landscape: consequences of non-agricultural re-use of redundant farm buildings in Friesland. Landscape and urban planning, 70, 143-152.

www.erfdelen.nl. Website consulted April 2024.

1 Empathic & caring living environment: **Conference paper**

Constructing the lived experience of older adults with dementia: lessons learned from an explorative mixed method approach

Leonie van Buuren[1*], Coosje Hammink[2], Masi Mohammadi[1,2], Daantje Derks[3], Nienke Moor[2]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[3] Erasmus University Rotterdam, The Netherlands

* Corresponding author: Leonie van Buuren (l.p.g.v.buuren@tue.nl)

Abstract: Understanding the lived experience of older adults with dementia is crucial in providing better care and living environments. However, a suitable and practical methodological approach is lacking to map this lived experience. These methods need adaptations due to dementia-caused behavioral, cognitive, and linguistic challenges. This paper aims to demonstrate innovative approaches for gaining a deeper understanding of the lived experiences of older people with severe dementia in collective spaces in nursing homes. An empirical mix-method study approach was used, combining fly-on-the-wall observations (including facial expression scales), physiological measuring (i.e., HR, HRV, PR, SCL, skin Temperature), and informal interviews. Based upon these measurements (n=20 people with dementia in four nursing homes), it turned out that the combination of spatial, behavioral, and biometric data provides a detailed and nuanced image of the lived experience of people with dementia in nursing homes. Practical recommendations to conduct this type of research are provided; for example, developing a baseline per participant, mapping activities in detail and carefully over time to link the different types of data, and conducting informal interviews to collect background information, preferences, and possible incentives or explanations of behaviors.

Keywords: lived experience, dementia, observations, physiological measuring, interviews

1. Introduction

The concept of "lived experience" is integral to understanding and improving the quality of life for individuals, particularly those who may not be able to fully articulate their needs and experiences. This concept encompasses the daily activities, experiences, and emotional responses of individuals. However, a significant challenge arises in interpreting the behaviors of people with dementia, who often exhibit behaviors and emotions that are difficult to interpret, such as apathy, agitation, inactivity, and limited engagement (Aboseif & Woo, 2020; Cerejeira, et al., 2012; Edvardsson, et al., 2014; Nording, et al., 2017).

Understanding the lived experience of this target group is crucial not only for providing better care but can also be used to improve living environments. This understanding helps to tailor care practices and environments to meet the unique needs of these individuals, fostering a higher quality of life and wellbeing (Beerens, et al., 2016; Heggestad, et al., 2015; van Zadelhoff, et al., 2011).

Current research methods for mapping people's lived experience are often qualitative in nature and encompass methods such as interviews or diary studies. However, in research focused on individuals with dementia, these language-centric approaches can be limiting due to linguistic challenges and cognitive impairments often prevalent in people with dementia (Driessen, 2019; Hirschauer, 2006; Pols, 2005). The lived experience focuses on how people feel when living their daily lives and executing their daily activities. However, little research focuses on this experience for people with dementia (Bower, et al., 2019). Research that does, often uses self-reports and interviews (Stanyon, et al., 2016). However, these methods are difficult to apply to people with dementia (Arons et al., 2013) due to the inherent cognitive decline, specifically in recalling past events and emotions (Jones et al., 2016). Furthermore, interviews with care professionals or family about the feelings of people with dementia can provide potential social desirability bias (e.g., showcasing positive effects of care activities) and retrospective bias (i.e., difficulties in recalling information when questions are asked retrospectively) and are therefore less suitable. (Shephard, 2003). Lastly, some research uses observational scales for people with dementia to measure mood and agitation (Edvardsson, et al., 2014). However, these methods are still interpretations of the experience of people with dementia by second parties.

Methods that gather information from the person as well as contextual factors (such as personal, social, organizational, and physical) can contribute to gaining insights into the lived experience of this particular target group. Examples of these methods are observations and physiological measuring. Despite some observational research, comprehensive studies on the daily activities of nursing home residents with dementia are scarce. In addition, previous studies often focus on observable physical activities rather than the emotional experiences accompanying them (den Ouden, et al., 2015; MacRae, et al., 1996). Mapping the affective responses of people with dementia requires innovative methods. Biometric sensor data, especially from wearable sensors, offers a promising approach. These methods provide detailed insights into affective states, unhampered by the challenges of declining speech and retrospective memory commonly found in people with dementia (Bourne, et al., 2019; Kreiberg, et al., 2010; Vos, et al., 2012). While studies have used physiological measures to assess the impact of interventions like music and art on mood and agitation in people with dementia, fewer studies have explored these measures in the context of daily life (Izzo, et al., 2021; Thomas, et al., 2018).

So, dementia is a complex condition that makes conducting research more challenging. Despite good attempts in current literature, the above mentioned challenges require adaptation in methods and approaches for people with dementia. While mixed-method approaches are common in qualitative research, insights and tools in practically applying these approaches in a reliable manner are scarce. Therefore, this research aims to demonstrate innovative approaches for gaining a deeper understanding of the lived experiences of older people with severe dementia in collective spaces in nursing homes using an empirical mixed-method approach including fly-on-the-wall observations, physiological measuring, and informal interviews.

2. Methods

An empirical study employing a mixed-method approach was conducted to investigate the lived experience of people with dementia residing in four nursing homes in the Netherlands. This approach aligns well with established empathic design methods (Mohammadi, 2017). The study's framework centers on observing what people with dementia do while measuring how they emotionally respond within the wards of these nursing homes, thus providing a deeper understanding of their lived experience. Conducted methods were fly-on-the-wall observations, physiological measuring, and informal interviews (see Table 1). This combination allows for a nuanced interpretation of affective states, identifying both positive and negative stress responses, arousal, and emotional states during activities (de Boer, et al, 2016; Tiberio, et al., 2019; Vos, et al., 2012).

The main focus of the paper is on the methodology. We piloted our methodology with a small sample and findings about the lived experience of older adults with dementia during the pilot phase are reported in the article of Hammink, et al. (under review).

Table 1. Research design overview

	The study
Methods to construct the Lived Experience (what people *do* and how they *emotionally respond*)	• Fly-on-the-wall observations, including observational scales • Physiological monitoring via biometric sensor (i.e., KANA and Empatica) o Measurements more continuously • Informal interviews with nursing staff and (if possible with) people with dementia
Sample	n=4 nursing homes: • Nursing home 1, care organization A • Nursing home 2, care organization B • Nursing home 3, care organization B • Nursing home 4, care organization C n=20 older adults with severe dementia

2.1 Sample

In total twenty participants with severe dementia (n=20) divided over four different nursing homes were involved. All participants lived in psychogeriatric wards of the nursing homes, had dementia (mostly Alzheimer's Disease, sometimes fronto-temporal dementia), and were capable of moving autonomously. Participants were recruited via nurses.

2.2 Fly-on-the-wall observation

The study employed the fly-on-the-wall observation method as recognizable outsiders (Zeisel, 1993) to observe daily patters and observable affective states in communal areas for two days per nursing home. This approach, informed by Zeisel's framework, involved observing who is doing what, with whom, in what relationship, context, and where (Zeisel, 1993; p124), complemented with three observational scales on mood and agitation (Appendix I). The observational scale for mood was based upon the Observed Emotion Rating Scale (OERS) (Lawton, et al., 1996) and the Maastricht Electronic Daily Life Observation Tool (MEDLO) (7-point Likert-scale, 1 for very negative mood and 7 for very positive mood) (de Boer, et al., 2016), while agitation was also assessed using MEDLO (5-point Likert-scale, 0 not present and 4 very agitated) (Appendix II). These scales were filled in by researchers and corroborated by nursing home staff to interpret the expressions of people with dementia (Lawton, et al., 1996). This observation data was collected via forms and annotated floorplans.

2.3 Physiological measuring

The rather innovative method to measure affective states physiological monitoring using wearable sensors was used in this study. The indicators Heart Rate (HR), Heart Rate Variability (HRV), Skin Conductance Level (SCL), Pulse Rate (PR), and skin temperature provide a more detailed view of the emotional responses to activities (Kreiberg, 2012; Tiberio, et al., 2019). The sensors KANA Daily Life (body-worn sensor on the chest) (Kana, n.d.) and Empatica Embrace Plus (wristband sensor) (Empatica, n.d.) were used in this study to measure these indicators. Based on literature, certain combinations of HR and HRV values, as well as high versus low values of SCL and skin temperature can be interpreted as relaxation, excitement, joy, anger, anxiety, fear, exertion, stress, focus, sadness, and contentment (see Figure 1) (e.g., Kana, n.d.; Kreiberg, et al., 2010; TaheriNejad & Pollreisz, 2017; Vos, et al., 2012; Jang, et al., 2015). For example, high values of HRV combined with high HR indicate excitement, while low HRV values and high HR values could indicate e.g. anger, stress, focus, as well as exertion. SCL reveals arousal, for example high SCL values could indicate e.g. anger, anxiety, as well as happiness, and low SCL could indicate non-crying sadness. Lastly, high skin temperature could indicate e.g., pain as well asl exercise, and low skin temperature could indicate stress. The shifts in the indicators' values are highly individual, therefore, the interpretation of high or low values should be considered within individual participants, not between participants (Hollien, 1980).

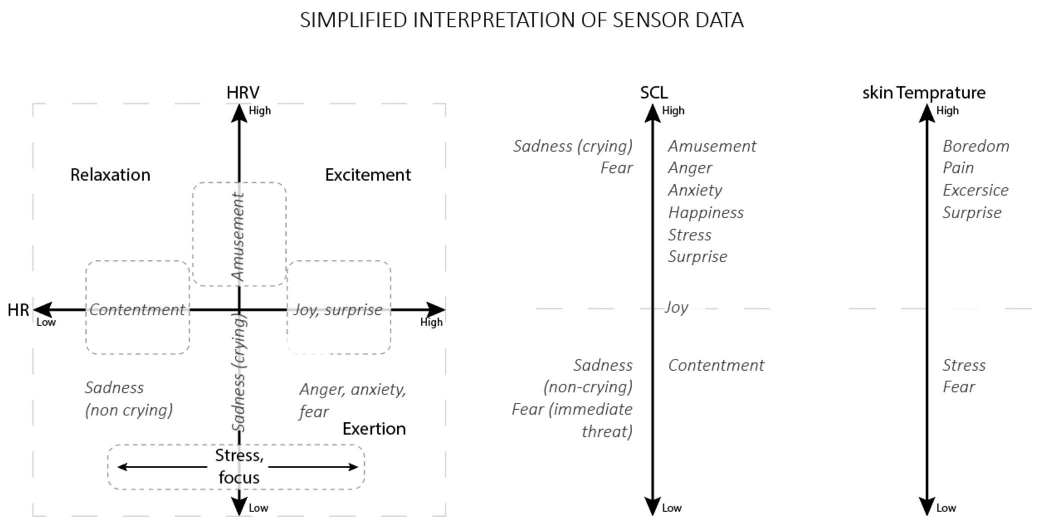


Figure 1. Simplified interpretation of biometric sensor data (indicators: HR, HRV, SCL, and skin Temperature)

2.4 Informal interviews

Additional informal interviews with care staff and participants before, during, and after the observations and measurements, provided background information about contextual factors and possible incentives or explanations for certain behaviors. This data was collected via fieldnotes.

2.5 Ethical approval

The Ethical Review Board of the Eindhoven University of Technology approved the setup of this study beforehand. Family members provided informed consent for the older adults with dementia in the nursing homes via staff members. Specific consent about wearing the sensor was obtained by people with dementia themselves, meaning that they could refuse to wear the sensor.

3. Results and analysis

During the main study, 1.993 unique observations have been registered over twenty participants with dementia in collective spaces of four nursing homes; with 28h and 48min sensor data with KANA and 100h and 20min sensor data with Empatica. This section provides preliminary results of the study; specifically focusing on examples of baseline development, long measurements, multiple indicators, and 'inactivity'-activities.

3.1 Baseline development

The interpretation of emotional responses is based on the peaks and drops in (physiological) values. Since this interpretation is highly individual (Hollien, 1980), developing a baseline per participant is essential. A baseline concerns a starting point – a kind of average emotional status of a person on that particular day – from which you can interpret whether a certain physiological value is high or low. This baseline can be developed by observing activities and visible expressions over a long period in combination with long physiological measurements and conversations with healthcare professionals and the participants themselves. Figure 2 shows an example of such a baseline, including the location of the participant, multiple physiological values (i.e., PR, skin T, SCL), emotional observational scales (i.e., MEDLO emotion and agitation), time of the day, and type of activities (e.g., walking, sitting, communication, eating & drinking, medication). The female participant often walked independently around the building (e.g., note #1). She loved participating in activities and conversations (e.g., #1, 3). During the measurement day, she suffered from a headache and repeatedly asked for paracetamol (#2). Nevertheless, she showed various emotional responses: satisfaction, pleasure, fear, interest, and sadness. This is visible in, for example, the different values in the MEDLO emotion observational sales. A value of four indicates a neutral emotional state, and a value of two (#2) implies signs of negative mood, such as sadness, displeasure, and anger, which was acknowledged by contextual observations since she was suffering from a headache and asking for paracetamol. Furthermore, the PR value increases (#2), which might refer to physical activity or stress.

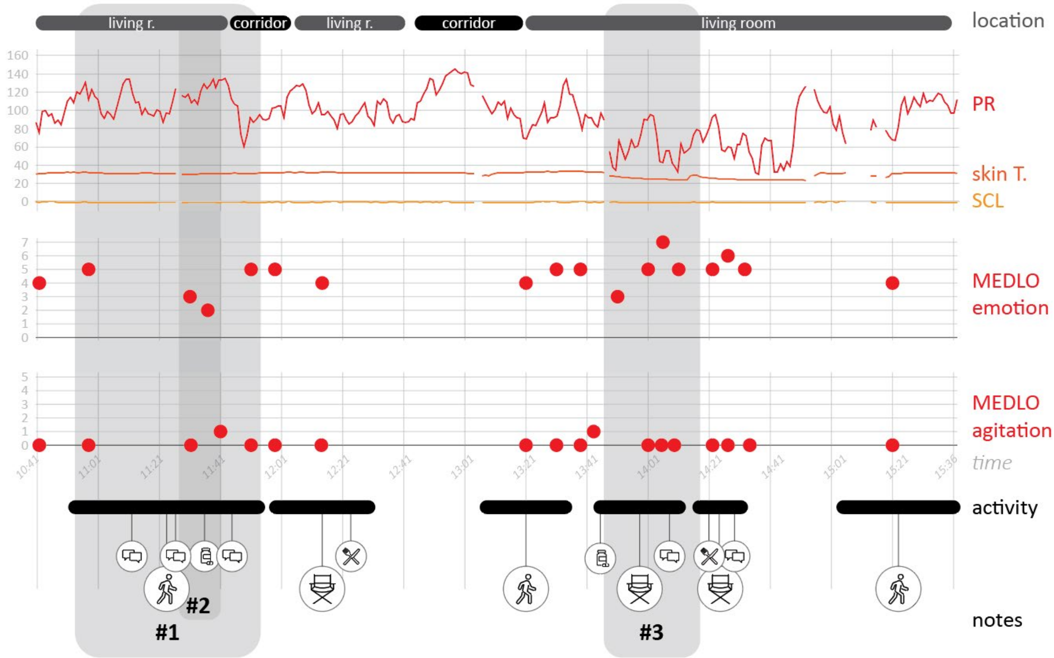


Figure 2. Example of a baseline, with location, physiological measures PR, skin Temperature, and SCL, observational scales of MEDLO, and activity. The notes refer to the text (Nursing home 4, participant A, day 1)

3.2 Measurement duration

While short measurements (2-10 minutes) provide insights into the stress response during a particular activity, longer measurements (30-60 minutes) could reveal better insights into recovery of activities and interpretations of affective responses. An example of a longer measurement is displayed in Figure 3. In this one-hour measurement, the HR and HRV values fluctuated (appointed by the arrows), just as the activities the participant performed (e.g., sitting, sleeping, chatting, walking). Based upon this longer measurement, we can interpretate the steepness of the peaks and drops of the HR and HRV values in a better manner, since we have a baseline including mean values as well.

For example, the drop in HR values in #1 is not that steep compared to the baseline; combined with the decrease in HRV value, this would indicate contentment rather than focus. Another example of the benefit of this baseline is the stabilization of the HRV value in #4, rather than a decrease in HRV value. Combined with the steep decrease in HR values, this would indicate relaxation, rather than being stressed, focused, or anxious. This relaxation is also acknowledged by the contextual observations: the participant could sit and relax again, after physical effort of the walk.

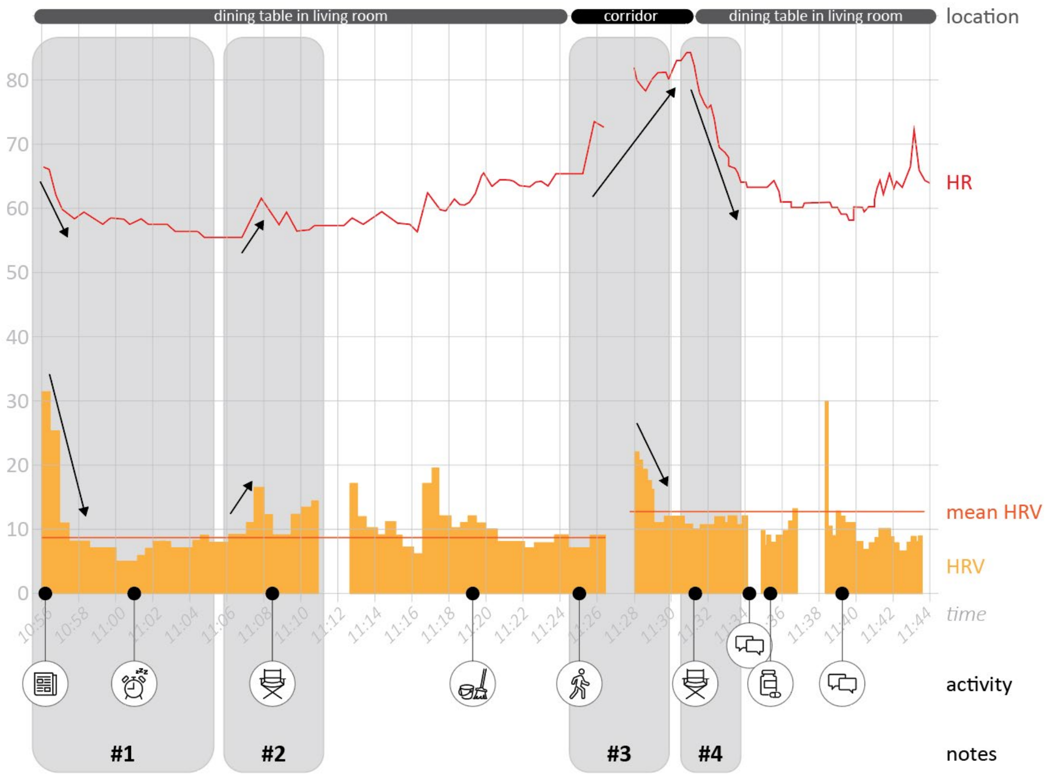


Figure 3. Example of a longer measurement, with location, increase/decrease arrows HR and HRV values, HRV mean, and activity. The notes refer to the text. (Nursing home 2, participant E, day 1)

3.3 Multiple physiological indicators

The combination of multiple indicators could reveal more insights into emotions; for example, during mobility scenarios in which HR and HRV values are not decisive. In this example, a participant was walking and searching for a given location, wearing both sensors (Figure 4). Based on the KANA sensor, the combination of HR and HRV values (#1) could indicate stress, focus, anxiety, fear, or exertion. The Empatica sensor provided additional information about skin temperature, PR, and SCL. An increase in skin temperature might exclude stress, anxiety, and fear. A drop in PR might also exclude stress. And the absence of peaks in SCL excludes stress as well. This exclusion leads to the possibility of exertion or focus; which she exhibited both. After #1, HR and HRV values increase, probably indicating excitement; which corresponds with the facial expressions and chatting activities.

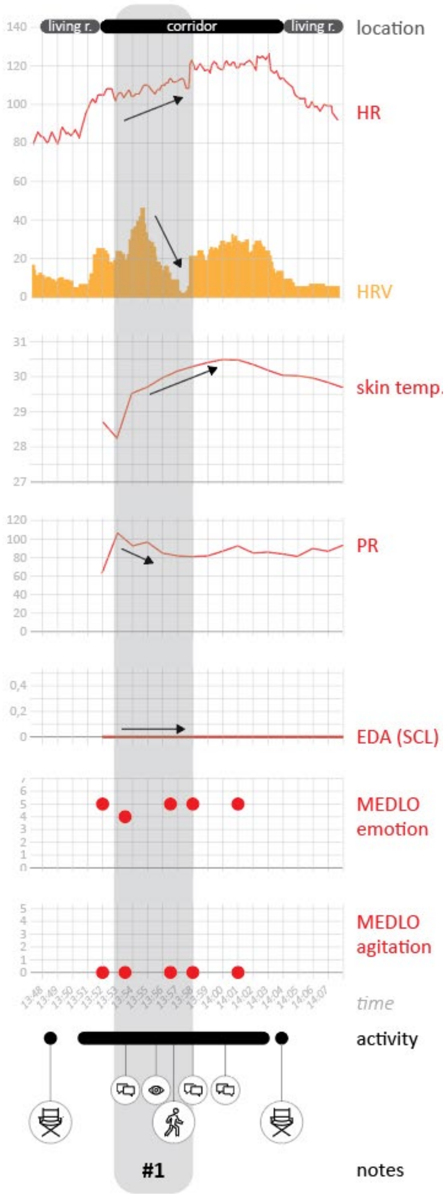
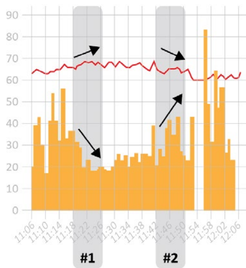
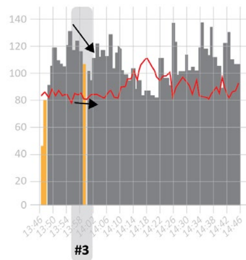


Figure 4. Example of the use of multiple physiological and observational indicators, with location, increase/decrease arrows, and the activity. The notes refer to the text (Nursing home 3, participant C, day 1)

3.4 Specify 'inactivity'-activities

Careful registration of the observed performed activities is crucial in interpreting the lived experience. Especially in the category of 'inactivity', what was exactly done and said by participants should be noted in detail. Various types of this 'inactivity' turned out to exist (e.g., sitting, standing, looking outside, watching TV, sleeping), and with different physiological measures. Table 2 displays examples of two different participants. The first participant is sleeping in her chair, while the second participant is sitting in the chair and might be focusing on the conversation surrounding him. Different emotional responses were interpreted.

Table 2. Two examples of different 'inactivities', displaying physiological and observational measures, including interpretation, the notes refer to the text in the table (*MEDLO, **OERS)

Observed behavior	Emotional response			Interpretation
	Sensor data (HR & HRV)	Notes	Observational scales	
Around 11:00h, the participant arrived in the living room and sat down on a chair. She closed her eyes often, **like she was sleeping**.		#1	Agitation: None Emotion*: Neutral (4 out of 7) Emotion**: Contentment	The combination of increase HR and decreased HRV could indicate focus. Sometimes, she was sleeping and sometimes she woke up. Neutral facial expressions. Did she wake up, but with her eyes closed?
		#2	Agitation: None Emotion*: Neutral (4 out of 7) Emotion**: Contentment	The combination of some decreasing HR and increase of HRV values could indicate relaxation. Just before this moment, she was chatting vividly, but now she is sleeping. It could indeed be relaxation.
Participant was sitting in the chair; he just had lunch. Surrounding him, people are talking. Sometimes, he joins the conversations, sometimes he **seems to listen to the conversation**.		#3	Agitation: None Emotion*: Neutral (4 out of 7) Emotion**: Contentment	The combination of stable HR and decreasing HRV could mean contentment or even focus. People around him were talking. Was he focused on the conversation surrounding him?

4. Discussion

To gain understanding in the lived experience of older adults with dementia, this paper aimed to demonstrate innovative approaches this lived experiences. The lived experience consists of what people do incorporated with how they emotionally respond. In this study, a combination of (informal) interviews, observations, and biometric measurements was applied.

4.1 Ethical considerations

How people experience something consists of several components (social, physical, mental/cognitive). Traditionally this experience is therefore mapped using different instruments relying on cognitive or mental aspects, i.e. interviews or surveys. For people with dementia this is done but with their (in)formal carer or using observational methods (i.e. mapping physical component). In short, research often talks about people with dementia. Of course this can also yield valuable information, but always involves the interpretation of somebody else regarding the experience of another person.

For people with dementia, specifically for those living in inpatient facilities, many assumptions are prevalent in practice and research regarding how certain 'behaviours' or 'environments' are experienced. However, the question remains whether, with the changes wrought by the dementia process, this is indeed the case. For example, assumptions were found during the selection of observational scales for this study about the definition 'inactivity'; is 'watching TV' indeed inactive? These kind of assumptions are particularly relevant for people with dementia experiencing many apathy symptoms and/or have difficulties in expressing themselves.

With advances in (biometric) technology, it is possible to retrieve more 'direct' information regarding physiological processes. Research in other target groups showed that this physiological data can give insight in bodily functioning, as well as into mood and wellbeing. Unfortunately, not much research goes into what (moderate to severe) dementia means for using biometric data. Our study tried to explore the potential of physiological measuring for this target group, combined with observational methods and informal interviews. While using only one method would be far cheaper and less time-consuming, the idea is that the combination of observational and physiological can give a more complete image of the lived experience of older people with severe dementia in nursing homes.

4.2 Four main insights

Four main insights were identified to conduct this type of research, including practical recommendations, and potential influential (technological) factors which can influence the research results: (1) combination of methods, (2) the use of multiple physiological indicators, (3) baseline development per individual participant, and (4) specify 'inactivity'-activities.

Combination of methods. Observations on behaviors and facial, body, and verbal expressions in combination with biometric data is key in interpreting the lived experience: they are interdependent and complementary. Physiological data can be used to objectively measure emotions, but you need observational (and interview) data to interpret the response. These combined data provide very valuable information, especially for this target group, where the expression of emotions is often disturbed.

Practically, observations should include *who, is doing what, with whom, in what relationship and who is the initiator, where, when and in what context, and which affective state.* It is important to register every detail. Before starting your research, you should decide carefully the method of registration (i.e., on paper in tables, or possibly using a tablet; not a computer).
Furthermore, nursing staff should be carefully involved in the whole process of the re-search; from explaining goals, to participant selection, observation procedures, application of the sensors, follow-up study. They can give important insights into the context and lives of the people they care for day in and day out. Informal interviews with them and – if possible – participants with dementia should be held upfront, during, and after the structured observations *to collect background information, preferences, and possible incentives or explanations of behaviors.*

The use of multiple physiological indicators. The use of multiple physiological indicators turned out to be of additional value in the interpretation of affective states; especially in combi-nation with observational data. While in this study HR, HRV, PR, SCL, and skin Temperature were used as indicators, other indicators like body posture or GPS trackers might be valuable for other research goals as well.

Some potential influential (technological) factors should be considered in future research concerning the physiological indicators. For example, more information about the effects of age, dementia and medication (e.g., heart medication) on indicators, such as HR, HRV, skin Temperature, and SCL, is necessary for even better interpretation (Perugia, 2018); since, for example, the algorithmic models for the interpretation of the data are now primarily based and trained with data from healthier and younger individuals. Furthermore, the application of the sensor may also affect data quality, due to the nature of changing conductivity of older skin (Barontini, et al., 1997) and due possible shifts of the sensor during movement. Lastly, one should be aware that some sensors need continuous Bluetooth connection, which requires a mobile phone to be in close contact with the participant throughout the movement.

Baseline development per individual participant. Whereas shorter measurements of physiological and observational data can give insights into people's stress response during a particular activity, more measures and longer measurements turned out to be important to interpret the readings by developing a baseline. Specifically, with (positive or negative) stressful activities, longer measurements can indicate whether the activity was stressful or strenuous: i.e., the longer it takes for HRV to recover, the more physically taxing the activity was. Furthermore, if after these activities HRV becomes very high, it may indicate that the previous activities were enjoyed.

The baseline should be constructed using the combination of physiological and behavioral methods, including the informal interviews. An average of physiological data can be calculated over the longer period of time and the data of the OERS and MEDLO scales can be plotted over this period of time. This makes it possible to interpret peaks and drops of data. This re-quires longer periods of observations, since it is also important to notice what participants say; because this could yield information about their emotions and mood (see section 'Baseline development' for an ex-ample). In addition, the baseline development includes knowledge about the type of dementia, because this could influence the mood (for example, possibly rapidly changing emotions in frontotemporal dementia). A complexity of constructing a baseline for people with severe dementia is the real life situation in a collective living room instead of a controlled laboratory free of (environmental) influences.

Practically, it is important to develop a *baseline per participant* with multiple and longer biometric measurements and observations, to interpret the biometric values of a particular activity. Beforehand, the most suitable indicators related to the research goal and best suited sensor for the individual participant should be selected and tested. The constructed baselines and specific activities should be *mapped and timed carefully over time to link the data*. During the measurements, one should also systematically keep track of who wore which sensor and when.

Specify 'inactivity'-activities. In this study, the category 'inactivity' was more specified accord-ing to the activity, e.g., sleeping, sitting and looking around, watching TV. Biometric data dif-fered during these activities; which could better nuance the lived experience of these types of activities. However, the duration of these activities turned out the be difficult to map.

5. Conclusion

In conclusion, the combination of spatial, behavioral, and biometric data using (informal) interviews, observations of activities and facial/body/verbal expressions, and multiple physiological indicators via wearable sensors provide a more detailed and nuanced image of the lived experience of people with dementia in nursing homes. While it is difficult to conduct research with people with severe dementia, it is extremely necessary and useful to gain proper understanding about their lived experience. In this paper, we would like to help future researchers by sharing our experiences and translating them into practical recommendations. Figure 5 shows the overview of the recommendations to construct the lived experience.

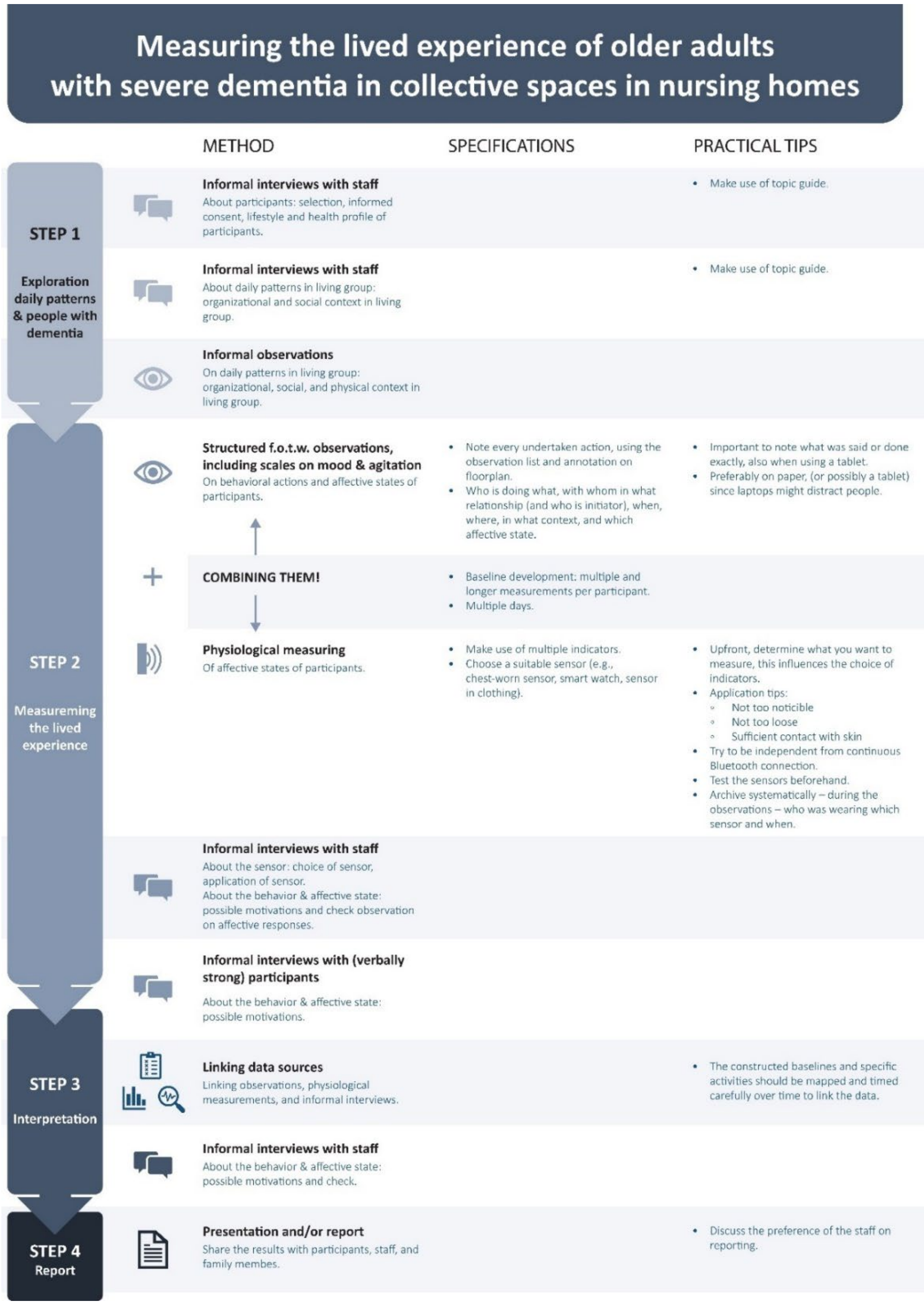


Figure 5. Recommendations to measure the lived experience of older adults with severe dementia in collective spaces of nursing homes

Acknowledgements

We would like to thank the care organizations Zorggroep Oude en Nieuwe Land, Oktober and Treant for their warm welcome, and the company Kana for their professional expertise.

References

Aboseif, A., & Woo, B. K. (2020). The stigma of dementia. In Genetics, neurology, behavior, and diet in dementia (pp. 633-645). Academic Press.

Arons, A. M., Krabbe, P. F., Schölzel-Dorenbos, C. J., Van der Wilt, G. J., & Rikkert, M. G. (2013). Quality of life in dementia: a study on proxy bias. BMC medical research methodology, 13(1), 1-8.

Barontini, M., Lázzari, J. O., Levin, G., Armando, I., & Basso, S. J. (1997). Age-related changes in sympathetic activity: biochemical measurements and target organ responses. Archives of gerontology and geriatrics, 25(2), 175-186.

Beerens, H. C., de Boer, B., Zwakhalen, S. M., Tan, F. E., Ruwaard, D., Hamers, J. P., & Verbeek, H. (2016). The association between aspects of daily life and quality of life of people with dementia living in long-term care facilities: a momentary assessment study. International psychogeriatrics, 28(8), 1323-1331.

Bourne, P., Camic, P., Crutch, S., Hulbert, S., Firth, N., & Harding, E. (2019). Using psychological and physiological measures in arts-based activities in a community sample of people with a dementia and their caregivers: A feasibility and pilot study. Journal of Aging Studies and Therapies, 1(1).

Bower, I., Tucker, R., & Enticott, P. G. (2019). Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: A systematic review. Journal of Environmental Psychology, 66.

Cerejeira, J., Lagarto, L., & Mukaetova-Ladinska, E. B. (2012). Behavioral and Psychological Symptoms of Dementia. Frontiers in Neurology, 3.

de Boer, B., Beerens, H. C., Zwakhalen, S. M. G., Tan, F. E. S., Hamers, J. P. H., & Verbeek, H. (2016). Daily lives of residents with dementia in nursing homes: Development of the Maastricht electronic daily life observation tool. International Psychogeriatrics, 28(8), 1333–1343.

den Ouden, M., Bleijlevens, M. H. C., Meijers, J. M. M., Zwakhalen, S. M. G., Braun, S. M., Tan, F. E. S., & Hamers, J. P. H. (2015). Daily (In)Activities of Nursing Home Residents in Their Wards: An Observation Study. Journal of the American Medical Directors Association, 16(11), 963–968.

Driessen, A. (2019). A Good Life With dementia: Ethnographic articulations of everyday life and care in Dutch nursing homes. Universiteit van Amsterdam.

Edvardsson, D., Petersson, L., Sjogren, K., Lindkvist, M., & Sandman, P.-O. (2014). Everyday activities for people with dementia in residential aged care: Associations with person-centredness and quality of life. International Journal of Older People Nursing, 9(4), 269–276.

Empatica (n.d.). Retrieved January 2024, from https://www.empatica.com/en-eu/embraceplus/

Hammink, J.H.W., van Buuren, L.P.G., Moor, J.A., Derks, D.A.J.A., & Mohammadi, M. (under review). Evolving dementia care: an explorative study on the lived experience of older adults living with dementia in nursing homes.

Heggestad, A. K. T., Nortvedt, P., & Slettebø, Å. (2015). Dignity and care for people with dementia living in nursing homes. Dementia, 14(6), 825-841.

Hirschauer, S. (2006). Puttings Things into Words. Ethnographic Description and the Silence of the Social. Human Studies, 29(4), 413-441. JSTOR.

Hollien, H. (1980). Vocal indicators of psychological stress. Annals of the New York Academy of Sciences, 347(1), 47-72.

Izzo, T. F., Candanedo, M. J. B. L., Higuti, A. Y., Corrêa, L. M., Campos, D. M., & Ansai, J. H. (2021). Immediate physiological effects of listening to music before physical exercise in institutionalized older people with dementia. Fisioterapia e Pesquisa, 28, 308-317.

Jang, E. H., Park, B. J., Park, M. S., Kim, S. H., & Sohn, J. H. (2015). Analysis of physiological signals for recognition of boredom, pain, and surprise emotions. Journal of physiological anthropology, 34(1), 1-12.

Jones, S., Livner, Å., & Bäckman, L. (2006). Patterns of prospective and retrospective memory impairment in preclinical Alzheimer's disease. Neuropsychology, 20(2), 144-152.

Kana (n.d.) Retrieved 25 June 2021, from https://kana.care/training-tools/kana-daily-life/

Khan, S. S., Spasojevic, S., Nogas, J., Ye, B., Mihailidis, A., Iaboni, A., ... & Newman, K. (2019, July). Agitation detection in people living with dementia using multimodal sensors. In 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (pp. 3588-3591). IEEE.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. Biological psychology, 84(3), 394-421.

Lawton, M. P., Van Haitsma, K., & Klapper, J. (1996). Observed affect in nursing home residents with Alzheimer's disease. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 51(1), P3–P14.

MacRae, P. G., Schnelle, J. F., Simmons, S. F., & Ouslander, J. G. (1996). Physical Activity Levels of Ambulatory Nursing Home Residents. Journal of Aging and Physical Activity, 4(3), 264–278.

Mohammadi, M. (2017). Empathische woonomgeving. Drukkerij Snep, Eindhoven, Eindhoven.

Nordin, S., McKee, K., Wallinder, M., von Koch, L., Wijk, H., & Elf, M. (2017). The physical environment, activity and interaction in residential care facilities for older people: A comparative case study. Scandinavian Journal of Caring Sciences, 31(4), 727–738.

Perugia, G. (2018). ENGAGE-DEM: A model of engagement of people with dementia. TDX (Tesis Doctorals En Xarxa). https://upcommons.upc.edu/handle/2117/168870

Pols, J. (2005). Enacting appreciations: Beyond the patient perspective. Health Care Analysis: HCA: Journal of Health Philosophy and Policy, 13(3), 203-221.

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires * Commentary. British Journal of Sports Medicine, 37(>3), 197–206.

Stanyon, M. R., Griffiths, A., Thomas, S. A., & Gordon, A. L. (2016). The facilitators of communication with people with dementia in a care setting: an interview study with healthcare workers. Age and ageing, 45(1), 164-170.

TaheriNejad, N., & Pollreisz, D. (2017). Assessment of physiological signals during happiness, sadness, pain or anger. In Wireless Mobile Communication and Healthcare: 6th International Conference, MobiHealth 2016, Milan, Italy, November 14-16, 2016, Proceedings 6 (pp. 107-114). Springer International Publishing.

Thomas, G. E., Crutch, S. J., Camic, P. M., & on behalf of the Created, S. (2018). Measuring physiological responses to the arts in people with a dementia. International Journal of Psychophysiology, 123, 64-73.

Tiberio, L., Cesta, A., Cortellessa, G., Padua, L., & Pellegrino, A. R. (2012). Assessing affective response of older users to a telepresence robot using a combination of psychophysiological measures. 2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication, 833–838.

van Zadelhoff, E., Verbeek, H., Widdershoven, G., van Rossum, E., & Abma, T. (2011). Good care in group home living for people with dementia. Experiences of residents, family and nursing staff. Journal of Clinical Nursing, 20(17-18), 2490-2500.

Vos, P., De Cock, P., Munde, V., Petry, K., Van Den Noortgate, W., & Maes, B. (2012). The tell-tale: What do heart rate; skin temperature and skin conductance reveal about emotions of people with severe and profound intellectual disabilities?. Research in developmental disabilities, 33(4), 1117-1127.

Zeisel, J. (1993). Inquiry by design: Tools for environment-behaviour research (reprint). Cambridge Univ. Pr.

Appendix I | Observation list (including 'what')

DATE:			LOCATION:							
nr	time	who	what	with whom	initiated by	what context	where	Mood 1	Mood	Agitation
1										
n										

Category	Subcategory	Activities
Inactivity	No activity	Doing 'nothing'
	Watching TV	Watching TV
	Sleeping	Sleeping
Activities of Daily Life (ADL)	Personal hygiene	Personal hygiene (e.g., washing hands)
		Put on glasses
		Put on hearing aid
		Taking drugs
		Wipe hands
	Go to bathroom	Go to bathroom
	Eating and drinking	Eating
		Drinking
	Mobility	Physiotherapy
		Transfer from point A to point B
		Looking at info signs and landmarks (for wayfinding purposes)
		Pronouncing aloud destination (for wayfinding purposes)
		Trying to open doors (for wayfinding purposes)
		Help of care professional / informal carer / fellow resident (e.g., p help, providing directions) (for wayfinding purposes)
		Arrival at destination (for wayfinding purposes)
		Traveled route (for wayfinding purposes)
		Stops on the route (for wayfinding purposes)
Instrumental Activities of Daily Life	Domestic activities	Setting the table
		Cleaning (e.g., sweeping, washing/drying dishes, dusting)
	Preparing food and drinks	(Helping with) preparing food (e.g., washing, peeling, cutting)
		Stir into drink with a spoon
Communication & hobbies	Communication	Verbal communication
		Non-verbal communication
		Visit
		Phone call (including video calls)
	Hobbies	Individual activities (e.g., reading, crafting, looking at pictures, etc.)
		Organized activities (e.g., sporting at the table, making music, gard playing games)
Remaining	-	-

Appendix II | OERS & MEDLO

Observational scales on mood

Table 1. Observed Emotion Rating Scale (OERS) (Lawton, et al., 1996)

Category	Signs
Pleasure	Smile, laugh, stroking, touching with "approach" manner, nodding, singing, arm or hand outreach, open-arm gesture, eye crinkled
Anger	Clench teeth, grimace, shout, curse, berate, push, physical aggression or implied aggression, like fist shaking, pursed lips, eyes narrowed, knit brows/lowered
Anxiety/fear	Furrowed brow, motoric restlessness, repeated or agitated motions, facial expression of fear or worry, sigh, withdraw from other, tremor, tight facial muscles, calls repetitively, hand wringing, leg jiggling, eyes wide
Sadness	Cry, tears, moan, mouth turned down at corners, eyes/head down turned and face expressionless, wiping eyes, horse-shoe on forehead
Interest	Eyes follow object, intent fixation on object or person, visual scanning, facial, motoric or verbal feedback to other, eye contact maintained, body or vocal response to music, wide angle subtended by gaze, turn body or move toward person or object
Contentment	Comfortable posture, sitting or lying down, smooth facial muscles, lack of tension in limbs, neck, slow movements

Table 2. Maastricht Electronic Daily Life Observation Tool (MEDLO) (de Boer, et al., 2016)

	Descriptive expressions
Negative: a negative mood can be characterized by groaning, moaning, crying, screaming, shouting, tensed facial expression or tensed body language. Furthermore, the content and tone of the verbal or nonverbal interactions gives information regarding the negativity of the mood.	
1	Great signs of negative mood (sadness, displeasure, anger, worries, fear, boredom or discomfort).
2	Considerable signs of negative mood (sadness, displeasure, anger, worries, fear, boredom or discomfort).
3	Small signs of negative mood (sadness, displeasure, anger, worries, fear, boredom or discomfort).
4	Neutral: a neutral mood is scored if there is no positive or negative mood observable, e.g. gazing or sleeping.
Positive: a positive mood can be characterized by smiling, laughing, chuckling, humming a tune, relaxed facial expression or relaxed body language. Furthermore, the content and tone of the verbal or nonverbal interaction gives information regarding the positivity of the mood.	
5	Small signs of positive mood (contentment, happiness, pleasure, relaxation, comfort).
6	Considerable signs of positive mood (contentment, happiness, pleasure, relaxation, comfort).
7	Great signs of positive mood (contentment, happiness, pleasure, relaxation, comfort).

Observational scale on agitation

Table 3. Maastricht Electronic Daily Life Observation Tool (MEDLO) (de Boer, et al., 2016)

	Deviating verbal expressions	Motoric agitation	Aggressiveness	Resistance to care (professional)
0	Not present	Not present	Not present	Not present
1	Low volume, not disruptive in milieu, including crying	Pacing or moving about in chair at normal rate (appears to be seeking comfort, looking for spouse, purposeless movements)	Verbal threats	Procrastination or avoidance
2	Louder than conversational, mildly disruptive, redirectable	Increased rate of movements, mildly intrusive, easily redirectable	Threatening gestures; no attempt to strike	Verbal/ gesture of refusal
3	Loud, disruptive, difficult to redirect	Rapid movements, moderately intrusive or disruptive, difficult to redirect	Physical toward property	Pushing away to avoid task
4	Extremely loud screaming or yelling, highly disruptive, unable to redirect	Intense movements, extremely intrusive or disruptive, not redirectable verbally	Physical toward self or others	Striking out at caregiver

1 Empathic & caring living environment: **Abstract livinglab DEEL**

Empathic Home
A stimulating environment catalysing self- and collaborative management

Masi Mohammadi[1,2], Toine van Lieshout[1], Gerald Gosselink-Ramos[1], Peyman Najafi[1], Erik Groen[1]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

The significance of housing conditions on individual autonomy among older adults with dementia is well-documented, highlighting smart home technologies as crucial for those wishing to continue aging in place. Despite their potential, the impact of these technologies on autonomy, particularly within spatial, care contexts, and in managing social interactions and personal behaviours, remains underexplored.

Technological advancements have catalysed the development of 'empathic homes'—emotionally intelligent environments designed to sensitively recognize, interpret, and adapt to the occupants' actions. These living systems are intricately engineered to support residents in overcoming physical, social, and emotional challenges, thus enhancing daily living and promoting self-management.

Grounded in the resilience and salutogenic models, this study aims to create predictive, supportive, and reliable environments that promote self-management and collaborative care. It seeks to develop a framework informed by the lived experiences of older individuals with dementia, illustrating how empathic homes enhance their living satisfaction and care efficiency. The framework focuses on developing methodologies to assess the impact of living concepts on quality of life, innovating improved concepts for housing and care services, and creating validated evidence to support enhanced well-being and reduce care burdens.

The research has led to the development of several home components, including the Guiding Environment and Cook3r, alongside a digital twin of the home for product refinement and feedback collection. Integrated into these responsive living spaces, these components provide sensory and user-centred designs that assist daily activities, employing sensor technologies and augmented reality for visual cues.

The application of technology in empathic homes not only aims to enhance physical safety but also to bolster mental health, transforming buildings into dynamic entities that significantly contribute to the well-being of their occupants. The study emphasises the need for ethical sensitivity and the importance of maintaining dignity and engagement for older people with dementia, ensuring that these technologies are employed respectfully and effectively.

Partners: This research project has been developed with the support of over thirty companies and organisations, under the supervision of HAN University of Applied Sciences and DEEL.

Funding: The project has received several grants from various sources, including the Taskforce for Applied Research SIA RAAK-MKB, the KIEM program, and Interreg.

Start date LivingLab: 2014
End date LivingLab: ongoing.

1 Empathic & caring living environment: **Abstract livinglab DEEL**

The lived experience of people with dementia

Leonie van Buuren[1], Coosje Hammink[2], Masi Mohammadi[1,2], Daantje Derks[3], Nienke Moor[2]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[3] Erasmus University Rotterdam, The Netherlands

The built environment influences people's (with dementia) behavior, their experiences, and their quality of life. How people behave and how they emotionally respond is captured in their lived experience. Understanding this lived experience is crucial in developing suitable housing and suitable care. However, limited knowledge is available on the lived experience of daily living of people with severe stages of dementia. Research methods to measure this lived experience of this particular target group are also lacking, due to linguistic and cognitive challenges of people with dementia. In this livinglab, we aim to provide insights into the relationship between the built environment, the activities/behavior of people with dementia, and their emotional responses (i.e., their lived experience) in collective spaces in nursing homes. Therefore, a suitable methodological approach should be developed and tested.

In this livinglab, a mixed method approach was applied, combining observations, physiological measurements, and informal interviews. So far, the lived experience has been explored for 28 people with severe dementia in five nursing homes in the Netherlands. First, daily patterns in socio-spatial context were identified, by spatial analysis of collective spaces (e.g., layout, daylight, colors, materials, furniture),fly-on-the-wall observations (i.e., who is doing what, with whom in what relationship, where in what context and when), and informal interviews with nursing staff and – if possible – people with severe dementia. Thereafter, the lived experience was measured during specific activities of daily living, among others eating & drinking, mobility, communication, 'inactivity'-activities (e.g., sleeping, sitting, watching TV), and hobbies. A combination of physiological measurement using two types of body-worn sensors (i.e., KANA and Empatica) measuring HR, HRV, PR, Skin Temperature, and SCL, in combination with observations on behavior and affective responses. Additionally, informal interviews with staff and – if possible – people with dementia themselves were conducted to understand certain behaviors, emotions, and possible motivations.

Contextual factors, such as physical, organizational, social, and personal, influence the lived experience, and should be taken into account carefully. Furthermore, the development of a baseline per participant is crucial in interpreting the lived experience of people with dementia.

Partners: TU/e, HAN, ZONL, Oktober, Treant, Kana

Start date LivingLab: September 2021

End date LivingLab: December 2026

1 Emphatic & caring living environment: **Abstract livinglab DEEL**

Inclusive and Caring Neighbourhoods: A framework for promoting social affordance and autonomy in dementia

Masi Mohammadi[1,2], Laurèn Pennings[1], Leonie van Buuren[1]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

As the population ages, integrating individuals with dementia into society becomes increasingly crucial. Maintaining their 'right to health' extends beyond healthcare access, including social determinants such as agency and secured freedom. Grounded in environmental psychology, urban gerontology, and empathic research methods, this study on social affordance underscores the role of the environment in shaping social behaviours. It translates the behavioural patterns, needs, and capabilities of this demographic into principles for interactive places that support their cognitive and social needs.

This research examines social affordance through a case study in Emmen, Netherlands, where the innovative open-door policy of a nursing home breaks traditional boundaries and enhances engagement by allowing residents with dementia to freely explore and participate within the neighbourhood. Preliminary findings from two PhD researchers and twelve master's students reveal that this policy enhances participant engagement and provides a foundational analysis of the daily activities of people with dementia, highlighting essential strategies for dementia-friendly neighbourhoods. Using a mixed-methods approach, this study combines quantitative data from environmental sensors and health monitoring systems with qualitative insights from interviews and behavioural observations.

As part of a broader plan, this policy underpins the development of a smart caring neighbourhood designed to respect the capabilities and conditions of these individuals within their social and care contexts. Employing technologies like GPS-enabled wearables, AI, sensor technologies, and interactive urban furniture, the neighbourhood aims to enhance daily activities and emotional connections, improving both individual well-being and community health.

The study emphasizes the convergence of place-making and smart healthcare policy and advocates for adaptable, ethically responsible urban solutions, fully aware of the socio-ethical complexities involved in using smart technologies to monitor and guide people with dementia. Ultimately, it aims to influence urban planning and health policies, establishing a sustainable, replicable model for inclusive urban living that supports individuals with dementia. Smart caring

neighbourhoods also aim to raise awareness, reduce stigma, and foster inclusiveness, thereby advancing urban health equity and promoting a more inclusive society.

Partners: Treant Care group, Housing association Domesta, Eindhoven University of Technology, HAN University of Applied sciences, and DEEL
Funded by: Treant Care group.

Start date LivingLab: 2024
End date LivingLab: 2029

1 Empathic & caring living environment: **Abstract keynote**

Designing for People Living with Dementia: Principles, Evaluation and Education

Habib Chaudhury[1*]

[1] Department of Gerontology, Simon Fraser University, Canada.

* Corresponding author: Habib Chaudhury (chaudhury@sfu.ca)

Supportive physical environment in long-term care settings can positively contribute to the quality of life for residents with dementia and the quality of care. There is substantial evidence that identifies the role of unsupportive physical environments contributing to responsive behaviours in people with dementia, e.g., spatial disorientation, anxiety, agitation, lack of engagement, social withdrawal. Conversely, a well-designed responsive physical environmental features can reduce anxiety and agitation, dependence in activities of daily living, and increase and enhance spatial orientation, social contact, mealtime experience. This presentation will highlight design principles to guide informed decision-making in planning and design of long-term care homes for older adults living with dementia and residents without dementia. The presentation will also provide an overview of an environmental assessment tool called "POET" for evaluation of long-term care homes. Finally, a newly developed educational game "Creating Home" to increase care home staff and other stakeholders' knowledge of the importance of the physical environment will be presented.

1 Emphatic & caring living environment: **Abstract keynote**

Designing happiness: key indicators of empathic and caring living environments for ageing well

Masi Mohammadi[1,2*]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

* Corresponding author: Masi Mohammadi (m.mohammadi@tue.nl)

Abstract: Our ways of living are continually evolving, influenced by broader socio-technological changes such as increased longevity, the rise of AI, and growing care demands. As societies now host more centenarians, significant questions arise about the adequacy of current care and housing systems to support these demographic shifts. Consequently, the need to adapt our living environments has never been more urgent.

"Designing Happiness" champions a systemic transformation in how we organise daily living for older individuals, exploring residential care through the lens of empathic and caring design. Research underscores the critical role of housing in societal development and how spatial design impacts our public health and happiness. These studies engage deeply with both the basic physical functionalities and the emotional, psychological, and social needs of individuals, particularly as they age.

Technological innovations are reshaping modern lifestyles, health expectations, and care systems., and they are increasingly capable of recognizing and processing human emotions with nuance—a critical aspect of empathy. As the German philosopher Hermann Schmitz remarked, living is the 'cultivation of emotions in space.' Integrating these technologies into the living environments of older people requires more than just the application of medicine dispensers; it involves a comprehensive approach that also accounts for socio-emotional and aesthetic resonance. This transformation turns smart care homes into spaces that anticipate diverse needs while fostering individual capabilities and agency. The interplay between these aspects is crucial, not just for individual health but for community well-being, necessitating transformations that extend to immediate surroundings and amenities.

Drawing on case studies from the Netherlands conducted in various Living Labs, this keynote talk examines the integration of smart architectural concepts and cross-disciplinary strategies to create healthy, inclusive environments that celebrate longevity. Utilising creative development approaches and multilevel collaborative methods, these real-life projects serve as

the foundation for co-creation with stakeholders, addressing both the technological and social dimensions of developing safe, engaging, and caring environments for all, including those with dementia.

Key findings indicate dynamic growth in technology integration, although sustained application in practice remains challenging. Systemic changes in governance and infrastructure must prioritize social and mental health with effective technology integration, focusing on sustainable usage within daily routines rather than merely efficiency.
Redefining the intersection of health and technology within architectural paradigms, discussions focus on the harmonious interplay among behaviour, belonging, agency, and the socio-organizational environment. These are crucial in creating places that understand, stimulate, and care for people. This intricate relationship, influenced by various environmental indicators, underscores the need for design solutions that are responsive to diverse socio-economic and cultural contexts, especially for older people with dementia. 'Designing Happiness' contributes to the discourse on adaptive and sustained living strategies, ensuring safety, familiarity, and reliability in smart environments.

Keywords: Empathic Design Socio-Emotional Design, Long-Term Care, Smart Living Environments, Happiness

1 Empathic & caring living environment: **Abstract workshop**

Hoe bouwen we dementievriendelijk?

Anne de Boer[1], Anne van Grinsven[2]

[1] Alzheimer Nederland, The Netherlands

[2] Woonzorg Nederland, The Netherlands

De hoeveelheid mensen met dementie groeit sterk en dat vraagt aandacht in hoe we onze huizen en wijken bouwen. Wat ervaren mensen met dementie en hoe bouw je hiervoor? Omdat de omgeving van invloed is op mensen met dementie, kunnen we in de (ver)bouw dementievriendelijke keuzes maken. Zo kun je de omgeving benutten om langer en zelfstandig in een eigen woning te blijven wonen. Alzheimer Nederland, Woonzorg Nederland en de Technische Universiteit van Eindhoven hebben de handen ineengeslagen om een dementievriendelijke toolkit te maken. Specifiek richt de handreiking zich op ontwikkelaars, complexbeheerders en huurders die vanuit een woningcorporatie betrokken zijn bij de verschillende fasen van het bouw- onderhouds- en transformatieproces. Het gaat dus om nieuwbouw én bestaande bouw, specifiek gericht op de nultredenwoningen. Het is een vervolg op de oude toolkit “dementievriendelijk ontwerpen”. Met behulp van illustraties worden een aantal thema’s die belangrijk zijn voor een dementievriendelijk woongebouw samengevat en tekstueel toegelicht. Aan de hand van een ervaringsoefening en voorbeelden voor dementievriendelijk bouwen, gaan we met elkaar in gesprek.

2

Adaptive & regenerative built environment

2 Adaptive & regenerative built environment: **Conference paper**

Understanding Household Willingness to Provide Demand Response and its Impact on their Electricity Cost

Sara Willems[1*], Dirk Saelens[1, 2]

[1] KU Leuven, Dept. of Civil Engineering, Building Physics and Sustainable Design, Belgium

[2] EnergyVille, Belgium

* Corresponding author: Sara Willems (sara.willems@kuleuven.be)

Abstract: The rise in intermittent renewable energy sources underscores the importance of residential demand response in balancing supply and demand. Households can contribute by adjusting appliance operation time or heating schedules. Understanding household willingness to engage in demand response and its impact on electricity costs is therefore crucial. To explore this, mixed-method case studies were conducted in 25 Belgian dwellings within the 'oPEN Lab' living lab, comprising a survey on their willingness, electricity demand measurements, and simulations for a subset of cases of active shifts in the appliance demand as well as passive shifts in the heating demand by employing a model predictive controller (MPC). Overall, household willingness to engage in demand response was found to be limited. The willingness to shift the use of the dishwasher, washing machine, and dryer is slightly higher than that for other appliances. Half to two-thirds of households accept adjusting thermostat settings at certain times. Preferences for tariff structures and for active or passive participation differ. Furthermore, it was found that current hourly variable electricity tariffs fail to incentivize demand response effectively. No or only marginal cost reductions are achieved when shifting the usage of white goods. With MPC for heating, cost reductions are lower in the case of hourly variable tariffs than monthly or quarterly variable ones, therefore stimulating not to shift demand to appropriate moments.

Keywords: demand response, electricity costs, households, willingness

1. Introduction

Human and natural systems are being exposed to more risks, such as increasing severity and frequency of extreme weather, caused by increasing greenhouse gas emissions (Kazim, 2007; Lima et al., 2017; Reichstein et al., 2013). In order to reduce its carbon footprint, the 'energy transition' from fossil-based dispatchable generation towards renewable energy sources such as wind and solar power at the supply side is required (Dupont et al., 2014; International Energy

Agency, 2022). The energy, generated by these renewable sources, is easily distributed via the electricity grid. The sources themselves are however less controllable, less predictable and more variable than fossil fuels. Electrical utilities will therefore be challenged in maintaining the demand–supply balance (Martinez et al., 2022; Sarran et al., 2021).

To maintain the demand-supply balance in the future, demand response will become important. It refers to (in)direct changes in energy demand by end use customers or prosumers from their normal patterns in response to signals, like prices (Arteconi et al., 2016; Dupont et al., 2014; Martinez et al., 2022).

More research is required on household willingness to provide demand response and the impact of demand response on their energy costs. The potential of demand response in supporting the demand-supply balance depends on households' willingness to provide it. This willingness varies between households. For instance, it is found that the willingness increases when more time is spent at home and when there is more access to enabling technologies (Parrish et al., 2020). The reason why households engage in demand response differs as well. Some households participate because of financial reasons, others for environmental ones, and others to provide community support (Chitchyan et al., 2019). Furthermore, it is essential that demand response programs are tailored to households' socio-economic status. Otherwise the program risks carrying distributional consequences, like higher bills or unhealthy conditions for low-income ones (Khan et al., 2019; Li et al., 2022; Ormandy & Ezratty, 2012; Trotta et al., 2022). However, the willingness of households to provide demand response and its impact on their energy costs are not yet well understood. Household energy demand is more complex and random as compared to, for instance, industry (Venkatesan et al., 2012). Moreover, the different household activities offer small shifts in terms of energy quantity but there are many of them (Shimoda et al., 2020). In addition, there is a large diversity between households in their willingness (Parrish et al., 2020).

To improve this understanding, a distinction should be made between passive and active participation. Passive participation involves technology like electrical storage, thermal boilers, or controllers (e.g. model predictive controllers (MPC)) of smart thermostats or smart white good appliances to manage set point temperatures and operation times. Active participation involves adapting energy-related behavior on a conscious basis or changing the constraints, such as the minimum and maximum set point temperature, of the controllers described above. In this context, this paper aims to improve the understanding of household willingness to provide demand response through active or passive participation as well as the estimated impact of both on their electricity cost. The estimated impact on the cost is calculated when active participation involves shifting the use of the washing machine, dishwasher, and dryer in time and when passive participation involves MPC for electric air-to-air heating.

2. Methods

The methodology consisted of two parts. First, the willingness to provide demand response of households from the 'oPEN lab' living lab was analyzed based on a survey. Secondly, the impact of demand response on the electricity cost was estimated by simulating shifts in electricity demands for a subset of cases. The living lab and both parts of the analysis are described in more detail below.

2.1. oPEN Lab living lab

The research focuses on the 'oPEN Lab' living lab in Genk (Belgium), which aims to become a positive energy neighborhood. It currently contains 25 occupied social rental properties. Table 1 contains an overview of the dwelling characteristics and Table 2 of the household characteristics. The dwellings are currently in their pre-renovation stage, with the renovation planned between February and June 2024.

Table 1. Characteristics of the dwellings

Characteristic	Values
Building type [%] (detached; semi-detached; apartment)	0.075; 0.85; 0.075
Total floor area [m^2] (min; average; max)	68; 112; 120
Protected volume [m^3] (min; average; max)	191; 332; 441
Estimated heat loss coefficient [W/m^{2}K] (min; average; max)[1]	50; 318; 644
n_{50} value (min; average; max)[2]	3.8; 6.6; 10.4
Heating system based on gas [%]	100 %

Table 2. Characteristics of the households

Characteristic	Values
Number of household members (average; standard deviation)	3.6; 1.7
Average age of the household members (average; standard deviation)	40; 20
Neto income of the household (average; standard deviation)	1350; 520

[1]The heat loss coefficient quantifies the power required to maintain a 1 degree Kelvin indoor-outdoor temperature difference over the entire building envelope [W/K] and accounts for both the thermal resistance and airtightness of the envelope. The reported values are calculated from measurements in 12 dwellings using the ARX method.

[2]The n50 value represents the air change rate occurring as a result of air leakage through the building envelope when an air pressure difference of 50 Pa exists between inside and outside. The reported values are based on blower door tests at 11 dwellings.

Willingness to participate in demand response was analyzed using data from all 25 households of the living lab, while demand response's impact on electricity costs was assessed for a subset of cases. Shifts in the use of the washing machine, dishwasher, and dryer was simulated for three cases, each varying in household characteristics and the availability of these appliances. Case 1 comprises a family with two adult children, Case 2 an elderly couple, and Case 3 a single adult. The dwelling in all three cases is semi-detached. The impact of MPC on electric heating demand was simulated for Case 1, considering the dwelling's post-renovation state.

2.2 Household willingness to provide demand response

The willingness to provide demand response of households from the 'oPEN lab' living lab was analyzed based on a survey, as described below.

2.2.1 Data Collection

A survey was distributed to understand household willingness to provide demand response. It consisted of an orally administered questionnaire with additional in-depth questions. The questionnaire included questions about characteristics of the dwelling, characteristics of the household members, the use of heating in the heating season, and household willingness to shift their energy demand. The questionnaire was based on the one of the 'Vlaams Kennisplatform Woningrenovatie' (Flemish Knowledge Platform for Dwelling Renovation) (Kennisplatform renovatie, n.d.), the one of the Department of Civil and Environmental Engineering (CEE) of the Michigan State University (Michigan State University, n.d.), and the one of the Center for the Built Environment (Peretti & Schiavon, 2019). The questionnaire was administered orally. In this way, the responses from households were better comprehended. Moreover, it facilitated the clarification of questions, beneficial as many households were unfamiliar with demand response, and it alleviated the workload for households. Furthermore, it enabled asking additional un-structured in-depth questions during the questionnaire administration process. Social desirability bias was reduced by assuring responses will be kept confidential, by establishing a rapport with respondents, creating a comfortable environment and building trust during the full pre-renovation monitoring process, by asking further in-depth questions when answers could be influenced by what is socially desirable, and by asking the questions in a neutral and non-judgmental manner. An audio recording was made of the conversation.

2.2.2 Data analysis

To understand household willingness to provide demand response, percentages of households giving certain answers were calculated. Moreover, the audio recording was listened to again and a summary was made of each conversation. This enabled to obtain a more in-depth understanding of household willingness.

2.3 Estimated impacts of demand response on electricity costs

The impact of demand response on the electricity cost was estimated by simulating shifts in the electricity demand for white good appliances for three cases and for heating via MPC for one of them. The simulations built on data about the households' electricity demand and online data on electricity prices. To shift the demands, models were set up. By using these models, the impact of demand response on electricity costs could be estimated. The collected data, models, and way in which the costs were calculated and analyzed is described in more detail below.

2.3.1 Data collection

Long-term measurements of the electricity demand were conducted at the living lab.[3] The electricity demand was measured via the digital meter. In this paper, the focus is on the data gathered in 2023 at the three cases discussed above. Note that for Case 1, there is 1 % of missing data; for Case 2 4 %, and for Case 3 1 %. In addition, the measurements in Case 2 did not start until March 1st . Table 3 provides more information about the sensors.

Table 3. Characteristics of the measurement devices

Name device	Measured parameters	Unit	Sampling rate
HomeWizard Wi-Fi P1 Meter	Electricity demand	kWh	15 min.
LoWi3 Wi-Fi P1 meter	Electricity demand	kWh	5 min.

Electricity price data was sourced online. A distinction was made between a standard and a social tariff[4] as well as between tariffs that vary in the long term (i.e. monthly or quarterly) and in the short term (i.e. hourly). An overview of the different components of these tariffs is given in Table 4. The energy component includes the monthly variable electricity prices for a standard tariff (VREG, 2024), the quarterly variable electricity prices for a social tariff (VREG, 2024) or the hourly variable day-ahead reference price (Elia Group, 2023). For the first, values for a dwelling with an annual energy demand of 3500 kWh and an average monthly peak of 4.26 kW were considered appropriate. These electricity prices were summed with the prices for transmission and distribution and the levies that apply in the case of a standard (VREG, 2024) or a social tariff (CREG, 2024). In the case of a hourly variable tariff, also the average of the monthly additional service costs charged by different energy suppliers was taken into account (Mijnenergie, 2024).

Table 4. Overview of the minimum, average and maximum prices of the different components of electricity tariffs in 2023.

Tariff type	Energy component [euro/kWh]	Transmission and distribution costs [euro/kWh]	Levies [euro/kWh]	Additional service costs [euro/month]	VAT [%]
Social quarterly variable	0.19: 0.17; 0.21	0.07; 0.08; 0.08	0; 0.02; 0.02	NA	0.06
Standard monthly variable	0.12; 0.24; 0.36	0.09; 0.09; 0.10	0.02; 0.04; 0.05	NA	0.06
Social hourly variable	-0.12; 0.10; 0.33	0.07; 0.08; 0.08	0; 0.02; 0.02	6.12	0.06
Standard hourly variable	-0.12; 0.10; 0.33	0.09; 0.09; 0.10	0.02; 0.04; 0.05	6.12	0.06

Once all these costs were summed up, 6% VAT was added.

2.3.2 Models

The impact of shifts in the use of white good appliances on the electricity cost was estimated for three cases. The available white good appliances differ between them. For case 1, the use of the washing machine, dryer and dishwasher was shifted; for case 2 the use of the washing machine; and for case 3 the use of the washing machine and dishwasher. To identify the moments when these white good appliances actually operated, a baseload was visually determined based on the time-series data. If the measured electricity demand was higher than the baseload for at least 45 minutes, the white good appliances were considered to be operating. To determine the electricity demand of the white good appliances, the baseload was subtracted from the total electricity demand.

Five situations that differ in the extent to which households offer flexibility in white good appliances' operation time were taken into consideration. In the baseline scenario, electricity demands are not shifted. In scenario 1, the use of these white good appliances can, based on the Linear project (Linear Consortium, 2014), be shifted 3h40min forward or backward. In scenario 2, the use of these white good appliances can be shifted within one calendar day, but not to the period between 1h and 6h30. The households were assumed to be sleeping during these hours. In scenario 3, the use of these white good appliances can be shifted to all moments of the corresponding calendar day. In scenario 4, the calendar day before, the day itself, and the day after the original moment of use are considered as operation window.

[3]Note that the dwellings contain gas heaters. The energy demand for heating is therefore not included in the electricity measurements.

[4]The social tariff is a reduced tariff for certain categories of households (CREG, 2024). It is the same for all energy suppliers and is calculated every three months by the CREG, the Belgian Federal Commission for Electricity and Gas Regulation.

Furthermore, the impact on the electricity cost of shifts in the moments that the dwelling is heated was examined for case 1. To this end, the situation after renovation was considered. Since the dwelling has not yet been renovated, a two-zone building simulation model of the dwelling was set up in Dymola using the OpenIDEAS library (Baetens & Saelens, 2016; Reynders et al., 2021). For the situation after renovation, 5 cm mineral wool in the original walls and 18 cm as inside insulation, 29 cm mineral wool in the roof, an air-to-air heating system with a power of 5kW and a COP of 4, mechanical ventilation (3.6 $m^3/(h\ m2)$ in the day and night zone, supply temperature at 20 °C), and the outdoor conditions of a typical meteorological year in Uccle were taken. The indoor temperature and heating demand were then simulated for January when the set points indicated by the household in the questionnaire were applied. Based on these data, the dwelling was modelled as a grey-box RC model with two states, being one for the indoor temperature and one in the sensor, using the ctsmrTMB tool (Vetter, 2023). This model and a functional mock-up interface (FMU) of the building simulation model were subsequently linked to the MPC framework of Jafarinejad et al. (2023). The objective function of the MPC framework was optimized for the monthly or quarterly variable tariff as well as the hourly variable tariff. The optimized electricity demands were used to calculate the electricity cost for electric heating. To compare this cost with the one without a MPC, the electricity demand for heating was also simulated for a full year using the building simulation model and set point temperatures corresponding with the lower comfort bound of the MPC framework (0h-17h: 18.5 °C; 17h-0h: 20 °C).

2.3.3 Data analysis

After simulating shifts in electricity demand using the models, the electricity costs were calculated by multiplying the demand by the electricity price at each moment. Subsequently, absolute and relative differences in costs were determined between scenarios with a monthly/quarterly variable tariff and an hourly variable tariff, between scenarios with an hourly variable tariff and different operation windows for white goods, and between scenarios with and without MPC. The scenario with an hourly variable tariff and no shifts in electricity demand served as the baseline for this analysis.

3. Results and analysis

3.1 Respondents' willingness to provide demand response

Households can offer demand response by adapting the set point temperature of their heating or shifting their household activities in time. Respondents' willingness to adapt thermostat set points is outlined in Table 5. One-third to half of them never want to adapt their thermostat set point, indicating a desire to retain the current control over it. During the day on weekdays, willingness to adapt the set point temperature is highest, while it is lowest on Sundays. Respondents indicate orally that their willingness is highest when the household or the majority of its members are not at home during the day. Additionally, three respondents mention that temperatures can be reduced during the day because they are actively engaged in household activities at that moment.

Respondents' willingness to shift household activities is given in Table 6. The willingness to shift the use of the dishwasher, washing machine, and dryer is slightly higher compared to other appliances. Among respondents willing to shift appliances, these appliances and TV usage during weekdays can most often be shifted without preferences for the original moment. Cooking during weekdays and the washing machine and dryer during weekends are indicated the most as appliances that can be shifted but with preference for the original moment. Especially respondents with children and members with disabilities indicate orally the difficulty of shifting appliance use. They often have fixed household schemes. Furthermore, some respondents like to watch TV at certain moments.

Table 5: Willingness to adapt thermostat set points [in percentages, N = 25].

Adaptations thermostat [%]	05:00-09:00	09:00-12:00	12:00-15:00	15:00-18:00	18:00-00:00	00:00-05:00	Never
weekday	24	44	36	36	24	16	32
Saturday	24	24	24	36	28	16	44
Sunday	24	24	24	32	24	16	56

Table 6: Willingness to adapt household activities [in percentages]. Only the households possessing the indicated appliance were taken into account, with their quantity specified in the first column.

Activity [%]	Cannot be shifted	Can be shifted, but original moment is preferred	Can be shifted to each moment
personal hygiene weekday *[N = 25]*	72	8	20
personal hygiene weekend *[N = 25]*	68	8	24
cooking weekday *[N = 25]*	68	24	8
cooking weekend *[N = 25]*	64	12	24
dishwasher weekday *[N = 16]*	59	6	35
dishwasher weekend *[N = 16]*	53	6	41
washing machine/dryer weekday *[N = 25/18]*	48	16	36
washing machine/dryer weekend *[N = 25/18]*	44	28	28
computer weekday *[N = 17]*	67	6	20
computer weekend *[N = 17]*	67	13	20
TV weekday *[N = 24]*	64	0	28
TV weekend *[N = 24]*	68	4	24

Respondents' preferred tariff structure, preferred way of participating in demand response, and preferences with respect to both are shown in Figure 1. With respect to the tariff structure, the respondents could choose between incentive-based and price-based demand response programs. In the former program, households are incentivized to reduce or shift their electricity demand during moments when the electricity grid Is under stress. In the latter, electricity prices vary dynamically throughout the day, reflecting changes in supply and demand conditions in the electricity market, and households can access the prognosis of the dynamic prices for the next day online. Among the respondents that are willing to shift household activities, incentive-based demand response programs are slightly preferred over price-based ones (Figure 1A: 44 % versus 40 %). Respondents that prefer an incentive-based demand response program usually do so because they don't want to continuously monitor variable prices. Respondents that prefer a price-based demand response program do so because it gives more control over the timing of their electricity demand. As many respondents prefer passive participation in demand response as active participation (Figure 1B: 40 %). Reasons for these choices are similar to reasons why respondents prefer a certain type of demand response program. Respondents that prefer passive participation do so because they do not have to constantly focus on the timing of their electricity demand. Respondents that prefer active participation do so because it offers more control over the timing of their electricity demand. However, respondents that prefer incentive-based demand response programs do not necessarily prefer passive participation (Figure 1C). The same applies to price-based demand response programs and active participation (Figure 1C).

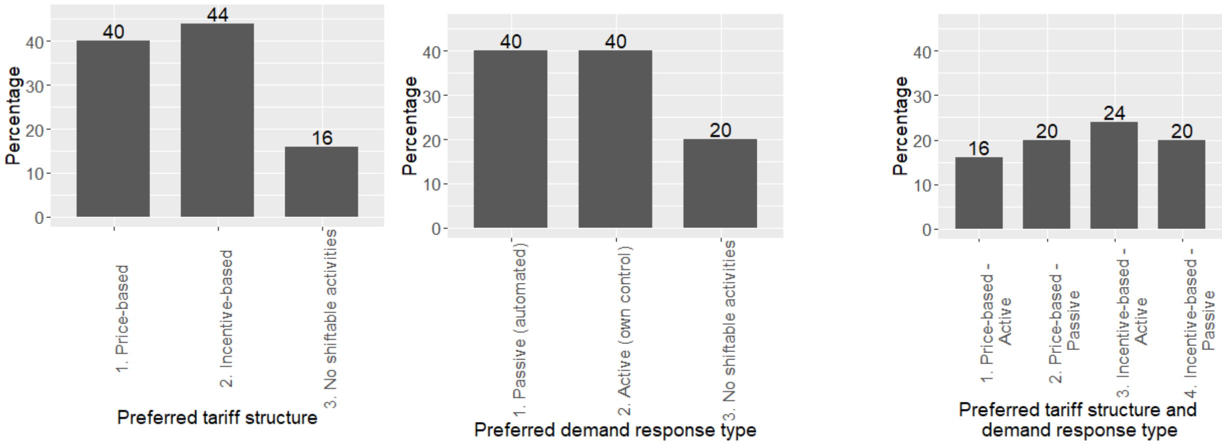


Figure 1: Preferred tariff structure (A), way of participating (B), and their combination (C) [in percentages, N = 25].

The impact of different motivators to engage in demand response are given in Table 7. For each of the motivators, respondents could indicate a value between 0 and 10, representing its level of motivation. The respondents are most motivated to engage in demand response because it involves a lower risk of power outages. Respondents express the importance of ensuring continuous access to electricity. Additionally, the positive environmental impact serves as a stimulus. Respondents express a willingness to contribute to environmental efforts. Monetary rewards and other incentives also encourage participation, albeit to a lesser extent.

Table 7: Impact of different demand response motivators, expressed as the average of the point given out of 10 and its standard deviation [N = 25].

Motivators [0-10]	Average	Standard deviation
Lower risk of power outages	6.1	3.7
The positive impact on the environment	5.5	3.6
Monetary rewards	4.6	3.3
Other rewards	4	3.6

3.2 Estimated impacts of demand response on electricity costs

Table 8 displays for three cases the annual electricity costs for using the washing machine, and if applicable, the dryer and dishwasher, in the baseline scenario and four scenarios with shifted usage times. Notably, under the baseline scenario, a standard monthly variable tariff is 17 % more expensive than an hourly variable one in case 1, 3 % more expensive in case 2, but 12 % cheaper in case 3. The reason for these differences is unclear. In the case of a social tariff, a quarterly variable tariff is 18 to 49 % cheaper than an hourly variable social tariff.

This is mainly due to the higher proportion of additional service costs associated with a hourly variable tariff. Moreover, in the case of a hourly variable tariff, shifting the demand in time with an operation window of 7h20 reduces the cost only with 3 to 6 % (scenario 1). Providing larger operation windows reduces the cost also with only 8 to 16 % (scenario 2-4).

Table 8: Roughly estimated impact of demand response on respondents' electricity cost in euro for different tariff structures [period: 01/01/2023-31/12/2023].

Case	Tariff type	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Case 1	Social quarterly variable:	€ 163 (82 %)	NA	NA	NA	NA
	Standard monthly variable:	€ 267 (117 %)	NA	NA	NA	NA
	Social hourly variable:	€ 200 (100 %)	€ 188 (94 %)	€ 184 (92 %)	€ 179 (90 %)	€ 170 (85 %)
	Standard hourly variable:	€ 227 (100 %)	€ 216 (95 %)	€ 212 (93 %)	€ 207 (91 %)	€ 198 (87 %)
Case 2	Social quarterly variable:	€ 77 (65 %)	NA	NA	NA	NA
	Standard monthly variable:	€ 134 (103 %)	NA	NA	NA	NA
	Social hourly variable:	€ 117 (100 %)	€ 110 (94 %)	€ 108 (92 %)	€ 107 (91 %)	€ 99 (84 %)
	Standard hourly variable:	€ 131 (100 %)	€ 124 (95 %)	€ 122 (93 %)	€ 121 (92 %)	€ 112 (86 %)
Case 3	Social quarterly variable:	€ 65 (51 %)	NA	NA	NA	NA
	Standard monthly variable:	€ 121 (88 %)	NA	NA	NA	NA
	Social hourly variable:	€ 127 (100 %)	€ 123 (97 %)	€ 121 (96 %)	€ 1191 (94 %)	€ 116 (91 %)
	Standard hourly variable:	€ 138 (100 %)	€ 134 (97 %)	€ 132 (96 %)	€ 130 (94 %)	€ 126 (92 %)

Table 9 illustrates the estimated effect of MPC on Case 1's heating electricity costs, electricity use and discomfort, with the latter expressed as the number of Kelvin hours that the indoor temperature is lower than the lower comfort bound. Implementation of MPC leads to cost reductions between 45 and 57 % in the case of, respectively, a standard monthly variable and a social quarterly variable tariff, and between 38 and 40 % in the case of hourly variable tariffs. Electricity use is reduced by approximately half and discomfort between 64 and 81 %.

Table 9: Estimated impact of MPC on Case 1's electricity cost, electricity use, and discomfort for different tariff structures [period: 01/01/2023-31/12/2023].

Case	Tariff type	Without MPC			With MPC		
		Cost	Electricity use	Discomfort lower bound	Cost	Electricity use	Discomfort lower bound
Case 1	**Social quarterly variable:**	€ 428 (103 %)	1199 kWh	807 Kh	€ 180 (43 %)	501 kWh (42 %)	292 Kh (36 %)
	Standard monthly variable:	€ 661 (129 %)			€ 283 (55 %)		
	Social hourly variable:	€ 416 (100 %)			€ 258 (62 %)	623 kWh (52 %)	151 Kh (19 %)
	Standard hourly variable:	€ 513 (100 %)			€ 307 (60 %)		

4. Discussion

The results suggest that the respondents will require a shift in mindset regarding demand response. Overall, there is limited willingness to apply it. Moreover, to encourage shifts in the use of washing machines, dishwashers, and dryers, the cost difference compared to non-shift scenarios should increase according to the three cases studied. The same applies to the utilization of MPC. Despite that MPC reduces electricity cost and use as well as discomfort significantly

in Case 1, an hourly variable tariff should be cheaper than a quarterly or monthly variable tariff. Failure to meet this criterion may result in heating demand not aligning with periods of high renewable energy availability. Eliminating the additional service costs would address this issue. Future research should enhance the methodology by incorporating non-intrusive load monitoring techniques for more accurate identification of household white goods' use (e.g. Angelis et al., 2022) and by questioning households' preferred operation window of these white goods. Additionally, improvements to the MPC framework are necessary, including the implementation of dynamic comfort bounds to accommodate households' comfort elasticities. These elasticities reflect how they adapt thermal comfort requirements in response to price fluctuations. They are defined as the ratio of the percentage change in the average temperature increase by heating to the percentage change in energy prices (Willems & Saelens, 2024). Moreover, future studies should expand the number of cases investigated. Furthermore, the effects on household electricity costs of passive participation in demand response through technologies like electrical storage or thermal boilers, as well as active participation through adjustments to controller constraints require future research. Finally, it is essential to explore whether households alter their willingness to adopt demand response when they understand its impact on their electricity costs and the environment.

5. Conclusion

This paper aimed to enhance the understanding of household willingness to engage in demand response through active or passive participation, and the impact on electricity costs when actively shifting white good appliance use or electric heating passively through MPC. The study focused on the oPEN Lab living lab in Genk, which comprises 25 occupied social rental properties.

Respondents' willingness to engage in demand response is generally limited. There is a slightly higher willingness to shift the use of dishwashers, washing machines, and dryers compared to other appliances. About two-thirds to half of the respondents are willing to adjust thermostat settings at certain times of the day. Willingness is expected to increase by awareness campaigns that highlight how hourly variable prices inform about how they can reduce the risk of power outages and their impact on the environment through their timing of electricity demand. At the same time, current tariff structures do not effectively incentivize demand response. While the implementation of MPC enables reducing electricity costs and use as well as discomfort in Case 1, demand response efforts with respect to white good appliances result in the three studied cases in only limited reductions, if any, in electricity costs.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037080 and from the Research Foundation Flanders (FWO), application number V426424N.

References

Angelis, G. F., Timplalexis, C., Krinidis, S., Ioannidis, D., & Tzovaras, D. (2022). NILM applications: Literature review of learning approaches, recent developments and challenges. Energy and Buildings, 261. https://doi.org/10.1016/j.enbuild.2022.111951

Arteconi, A., Patteeuw, D., Bruninx, K., William, D., & Helsen, L. (2016). Active demand response with electric heating systems: impact of market penetration. Applied Energy, 177, 636–648.

Baetens, R., & Saelens, D. (2016). Modelling uncertainty in district energy simulations by stochastic residential occupant behaviour. Journal of Building Performance Simulation, 9(4), 431–447. https://doi.org/10.1080/19401493.2015.1070203

Chitchyan, R., Shah, P., & Bird, C. (2019). Eliciting requirements for demand response service design to households: A pilot study. ACM International Conference Proceeding Series, 299–304. https://doi.org/10.1145/3319008.3319355

CREG. (2024). Sociaal tarief. https://www.creg.be/nl/consumenten/prijzen-en-tarieven/sociaal-tarief

Dupont, B., Dietrich, K., Dupont, B., Dietrich, K., Jonghe, C. De, Ramos, A., & Belmans, R. (2014). Impact of residential demand response on power system operation: A Belgian case study Impact of residential demand response on power system operation. Applied Energy, 122. https://doi.org/10.1016/j.apenergy.2014.02.022

Elia Group. (2023). Belgian Bidding Zone day-ahead reference price. https://www.elia.be/en/grid-data/transmission/day-ahead-reference-price

International Energy Agency. (2022). World Energy Outlook.

Jafarinejad, T., Erfani, A., Ritosa, K., & Saelens, D. (2023). Analysis of the influence of district thermal properties for enhancing energy flexibility through thermal mass activation. Journal of Physics: Conference Series, 2654(1), 012100. https://doi.org/10.1088/1742-6596/2654/1/012100

Kazim, A. M. (2007). Assessments of primary energy consumption and its environmental consequences in the United Arab Emirates. Renewable and Sustainable Energy Reviews, 11(3), 426–446. https://doi.org/10.1016/j.rser.2005.01.008

Kennisplatform renovatie. (n.d.). Innovatie in Renovatie. 2020. https://www.kennisplatform-renovatie.be/

Khan, I., Jack, M. W., & Stephenson, J. (2019). Identifying residential daily electricity-use profiles through time-segmented regression analysis. Energy & Buildings, 194, 232–246. https://doi.org/10.1016/j.enbuild.2019.04.026

Li, R., Satchwell, A. J., Finn, D., Haunstrup, T., Henze, G., & Wittchen, K. (2022). Ten questions concerning energy flexibility in buildings. Building and Environment, 223, 109461. https://doi.org/10.1016/j.buildenv.2022.109461

Lima, F., Nunes, M. L., Cunha, J., & Lucena, A. F. P. (2017). Driving forces for aggregate energy consumption: A cross-country approach. Renewable and Sustainable Energy Reviews, 68, 1033–1050. https://doi.org/10.1016/j.rser.2016.08.009

Linear Consortium. (2014). Demand Response for Families: Linear Report. http://www.linear-smartgrid.be/sites/default/files/Linear Final Report - lr2.pdf

Martinez, S., Vellei, M., & Dréau, J. Le. (2022). Demand-side flexibility in a residential district: What are the main sources of uncertainty? Energy & Buildings, 255, 111595. https://doi.org/10.1016/j.enbuild.2021.111595

Michigan State University. (n.d.). Kristen Cetin. 2024. https://engineering.msu.edu/faculty/Kristen-Cetin

Mijnenergie. (2024). Dynamische tarieven 2024: hoeveel betaal je met een dynamisch tarief? https://www.mijnenergie.be/blog/dynamische-tarieven-2023-hoeveel-betaal-je-met-een-dynamisch-tarief/

Ormandy, D., & Ezratty, V. (2012). Health and Thermal Comfort: From WHO guidance to housing strategies. Energy Policy, 49, 116–121.

Parrish, B., Heptonstall, P., Gross, R., & Sovacool, B. K. (2020). A systematic review of motivations, enablers and barriers for consumer engagement with residential demand response. Energy Policy, 138, 111221. https://doi.org/10.1016/j.enpol.2019.111221

Peretti, C., & Schiavon, S. (2019). Indoor Environmental Quality. Sustainable Construction Technologies: Life-Cycle Assessment, 107–122. https://doi.org/10.1016/B978-0-12-811749-1.00003-1

Reichstein, M., Bahn, M., Ciais, P., Frank, D., Mahecha, M. D., Seneviratne, S. I., Zscheischler, J., Beer, C., Buchmann, N., Frank, D. C., Papale, D., Rammig, A., Smith, P., Thonicke, K., Van Der Velde, M., Vicca, S., Walz, A., & Wattenbach, M. (2013). Climate extremes and the carbon cycle. Nature, 500(7462), 287–295. https://doi.org/10.1038/nature12350

Reynders, G., Erfani, A., & Saelens, D. (2021). IEA ANNEX 71- Building Energy Performance Assessment Based on In-situ Measurements. https://iea-ebc.org/projects/project?AnnexID=71

Sarran, L., Gunay, H. B., Brien, W. O., Hviid, C. A., & Rode, C. (2021). A data-driven study of thermostat overrides during demand response events. Energy Policy, 153, 112290.

Shimoda, Y., Yamaguchi, Y., Iwafune, Y., Hidaka, K., Meier, A., Yagita, Y., Kawamoto, H., & Nishikiori, S. (2020). Energy demand science for a decarbonized society in the context of the residential sector. Renewable and Sustainable Energy Reviews, 132, 110051. https://doi.org/10.1016/j.rser.2020.110051

Trotta, G., Rhiger, A., & Sommer, S. (2022). The price elasticity of residential district heating demand: New evidence from a dynamic panel approach. Energy Economics, 112, 106163. https://doi.org/10.1016/j.eneco.2022.106163

Venkatesan, N., Solanki, J., & Solanki, S. K. (2012). Residential Demand Response model and impact on voltage profile and losses of an electric distribution network. Applied Energy, 96, 84–91. https://doi.org/10.1016/j.apenergy.2011.12.076

Vetter, P. (2023). ctsmrTMB: Continous Time Stochastic Modelling in R using Template Model Builder. https://phillipbvetter.github.io/ctsmrTMB, https://github.com/phillipbvetter/ctsmrTMB

VREG. (2024). Hoeveel betaalt u als u vandaag een nieuw commercieel energiecontract afsluit? https://dashboard.vreg.be/report/DMR_Prijzen_elektriciteit.html

Willems, S., & Saelens, D. (2024). Estimating the Long-Term Thermal Comfort Elasticities of Diverse Households. BuildSim-Nordic Conference.

2 Adaptive & regenerative built environment: **Conference paper**

Shifting Agency Positions in Health and Wellbeing Transitions Agency of Municipalities in the local energy, health, and wellbeing transitions in The Netherlands

Maurice Coen[1*], Karin Landsbergen[2], Frits Schultheiss[2], Frank de Feijter[2], Erik Jansen[2]

[1] Nyenrode Business Universiteit, The Netherlands

[2] HAN University of Applied Sciences, The Netherlands

Western Norway University of Applied Sciences, Norway

* Corresponding author: Maurice Coen (m.coen@nyenrode.nl)

Abstract: Municipalities are dealing with multiple transitions in neighbourhoods including the energy transition. Although they have a decisive role in transitions in areas such as health, and well-being, it is often not possible to achieve the inevitable transformative changes from their singular perspective. Based on action research studies in the energy transition it appears that the options municipalities have to deploy agency in neighbourhood approaches may vary enormously. This also affects the options for realising the required transformative changes. In this paper, we share insights into the shifting agency positions of municipalities and the need to direct this agency on transformative change processes. We argue these insights can enable municipalities to take up the decisive role required in dealing with multiple transitions in neighbourhoods.

Keywords: energy transition; agency; municipality; health; well-being.

1. Introduction

Improving Health and Well-being is widely associated with the energy transition in the built environment, and this connection is understandable. Energy efficient renovation of buildings and homes is a crucial component of the energy transition, and it also leads to the resolution of health-damaging issues such as drafts, moisture, and mould. A comfortable home has positive effects on both wellbeing and health of residents (Middlemiss et al., 2023). However, there's more to consider. In the Netherlands, the energy transition (ET) in the built environment is guided by the National Climate Agreement (NCA) (Rijksoverheid et l., 2019) mandating a neighbourhood-based approach that integrates ET with social and physical challenges in the community. Since 2019, programs as Sustainability in Disadvantaged Neighbourhoods (SDN) (Uyterlinde et al., 2022; Uyterlinde & Can, 2023) fostered experimentation. For instance, in the

Selwerd neighbourhood (Groningen), health is prominently linked to the energy transition through the Sunny Selwerd initiative (Uyterlinde et al., 2022; Uyterlinde & Can, 2023). Other municipalities connect health and other challenges in neighbourhood approaches to the ET, including energy poverty, employment, and safety, as well as physical issues such as water management, heat stress prevention, and sewer replacement. Thus, the energy transition in the Netherlands not only addresses health and well-being directly by solving problems like drafts, moisture, and mould but also by integrating other neighbourhood-related challenges. In the NCA Dutch municipalities have been assigned a role as key actor, implying that they are crucial in connecting issues related to health and well-being with the ET. However, with experimental programs such as Sustainability in

Disadvantaged Neighborhoods (SDN), it becomes evident that the leadership role for municipalities is challenging and complex (Uyterlinde et al., 2022; Uyterlinde & Can, 2023). Experiences with the latter program (through the involvement of author M. Coen) indicate that municipalities, despite their designated key role, are often unable to foster transformative changes as a fundamental part of the ET. Such transformative changes concern profound technological and social alterations within a system (Termeer & Metze, 2019). Agency of actors, which can be understood as the capacity that agents (individuals or group) ossess to take action, is an important factor in successfully transforming systems in transitions. However, the current focus in the literature on agency in transitions is goal-oriented (Fischer & Newig, 2016). Insights on how actors' agency and actions contribute to, or influence transition processes are scarce (De Roeck & Van Poeck, 2023; Pesch, 2015). In most studies, agency is blackboxed as a possibility to act. Such perspective overlooks gaining insight into what ways the options for action can be shaped or in what way agency-options (means, knowledge, power) are deployed, and, in what way this specified effort contributes to the desired or unwanted change. Hence, it is unclear how agency can be practically shaped to yield transformative change. What stood out in the SDN program was the variation in options available to municipalities for executing agency within a neighbourhood, e.g. resource allocation, influence, and knowledge application. Upon initial exploration, agency options appeared contextually dependent, which could be one cause for the

challenges municipal leadership faces in realizing the transformative changes, as this presupposes fine-grained contextual sensitivity. In the municipality of Arnhem, an opportunity arose to further investigate this

phenomenon. The authors collaborate on Arnhem's energy transition across two settings in several projects, in which agency options of the municipality also appeared to shift. These two settings provided a fitting opportunity to analyse the contextuality of agency within a municipality. In this paper, we present our preliminary findings from this analysis.

2. Methods

2.1 Learning-projects

The study is based on two multi-year action-based learning-projects in Arnhem: Setting 1, the Arnhem Approach to Energy Poverty (AAEP) and Setting 2, the Arnhem Learning Approach (ALA) both associated with the Natural Gas Free Neighbourhood Approach originating from the NCA (Rijksoverheid et al., 2019). The issue of energy poverty was addressed in the Spijkerkwartier district, and the development of an affordable heating supply took place in the Elderveld Noord district. We focused on the role of the municipality's agency in both learning projects.

In Setting 1 (AAEP) the municipality of Arnhem aimed to develop an energy poverty mitigation approach in collaboration with a network of actors. In 2022 researchers from HAN University of Applied Sciences and Nyenrode Business University were asked to support the collaborative development and learning-bydoing process. Throughout the learning-project, six civil servants, three professionals from a housing association, a citizen volunteer and social entrepreneur, a volunteer from an energy support cooperation, an artist-consultant and three researchers participated. Six reflective learning sessions were organized on substantive issues, collaborative processes, and organisational themes. Concerted actions were planned to co-develop a joint integral practice. The researchers will remain involved in this project until at least the end of 2024.

In Setting 2 (ALA) the municipality aimed to develop a district energy retrofitting approach in collaboration with a network of actors with special emphasis on introducing a new collective heat district system in the neighbourhood that offers an affordable heat solution for citizens. In this approach, researchers from HAN University of Applied Sciences and Nyenrode Business University were asked in 2022 to support the collaborative approach and learning-by-doing while developing a learning methodology for this and similar transitions. The project team consisted of, among others, civil servants from various departments, professionals from housing associations, district heating companies, social engagement companies and grid providers. In this learning-project, eleven project group meetings were observed (fly on the wall), six reflective learning sessions were oorganized and multiple visits to residents have been made by professionals and students. The researchers will remain involved in this project until the end of 2024.

2.2 Approach

This study can be classified as an emergent case study according to Lee & Saunders (2017) because the data collection was not specifically designed to address the research question, but instead emerged organically during the learning projects in Arnhem. The study can be conceived as an emergent single case study. The term “single” signifies that we do not compare cases; rather, we aim to gain profound insights into the changing agency within two manifestations of the same case, i.e. a municipality, for theorizing (Yin, 2014; Siggelkow, 2007)

The participating actors were not involved through a selection procedure. In the context of learning projects, the actors were involved through a consortium formation process in which a dialogue was initiated with various actors when a shared task emerged.

The data sources for this study were the earlier mentioned two multi-year, action-research learning-projects. In these learning-projects, health and well-being play pivotal roles as central issues in the neighbourhoods in relation to the energy transition. Moreover, we focus on changing agency options within municipalities as

a common process in initiatives targeting complex social challenges during local transitions within the built environment.

The data, collected with a broader scope, comprises records from collaborative learning sessions, project group meetings, and interviews. It also includes observation reports, field notes, and reflective sessions conducted by researchers. Our data analysis employs thematic analysis (following Braun & Clarke, 2006), aligning well with the qualitative research nature and the intended theory-building aspect of this study. To give an impression, the table below shows two meaningful activities for each of the 2 learning projects.

Table 1. Activities in the learning-projects

Learning-project	Activity
AAEP	The first learning session in which interests, ideas and opinions were shared. The participants indicated that trust and cooperation were the most important issues that needed to be addressed first.
AAEP	A learning session in which the challenge of poverty was perceived as a disaster to which a rapid response was necessary. This gave the participants the tangible insight that the current policy system must be circumvented to link to the social context of residents
ALA	A learning session in which the participants together recalibrated the view and ambition of the assignment. The answers to the 'dream question' (What is your dream for the neighborhood?) revealed surprising and insightful differences between the participants
ALA	The visits to residents showed that it is difficult to inform residents about the natural gas-free target from a technological and top-down policy perspective. Specific skills are required to match these objectives with the every-day lifeworld and practices of householders

3. Results and analysis

The examples below have been adapted so that they cannot be traced to recognizable events or people in the neighbourhoods.

3.1 A composition of actors, issues, and activities

Improving Health and Well-being is widely associated with the energy transition in the built environment, and this connection is understandable. Energy efficient renovation of buildings and homes is a crucial component of the energy transition, and it also leads to the resolution of health-damaging issues such as drafts, moisture, and mould. A comfortable home has positive effects on both wellbeing and health of residents (Middlemiss et al., 2023).

In both neighbourhood settings, a multitude of complex challenges demanded attention. These encompass various issues, including Resident Participation: Engaging residents actively in decision-making processes; Affordable Heat Solutions: Developing cost-effective heating solutions; Social Imperatives: Addressing employment opportunities and health-related concerns; Physical Demands: Tackling climate mitigation, outdoor spaces, and sewer system upgrades. In essence, a neighbourhood approach involves grappling with a diverse array of issues, each intricately linked to the well-being and sustainable development of the community.

In both neighbourhoods, there is a network of actors working on the energy transition. The compositions of these networks show many similarities. However, the composition of the actors involved in the various issues differs substantially. The social entrepreneur, involved in the training of unemployed local residents as handymen to implement simple insulation measures in the homes of local residents, was not involved in decisioning on an affordable heating solution. And the network company, for example, was in turn not involved in energy poverty mitigation activities. Thus, the interests of the actors are not the same on every issue. Hence, the motivation to use the available options for action varies per issue.

3.2 Contextual agency option

The municipality's agency differs per overarching substantive issue for each setting. In the energy poverty learning-project, for example, the municipality played a decisive role in starting an experiment to train unemployed residents to implement simple isolating measures in local dwellings and could provide the social entrepreneur with resources to prepare and carry out the experiment (Setting 1). The same municipality, however, did not have that option for developing an affordable offer for a heating solution because the market parties had more stakes and power in that issue (Setting 2).

When examining the disparities in agency between these issues, we observed that, on the one hand, options available to municipalities for implementing agency diverged. For instance, in Setting 1, the municipality can leverage knowledge related to well-being and poverty, whereas in Setting 2, this is not feasible due to the primacy of relevant technical knowledge by other actors. On the other hand, the weight of a certain agency option varies across different contexts. Financial budgets, up to €100,000 may suffice to initiate an experiment in Setting 1, but in Setting 2, such a budget yields limited leverage. These nuanced distinctions warrant careful consideration during policy design and intervention implementation. Table 1 shows the different agency options of the municipality we observed for the issues of 'energy poverty' (Setting 1) and 'creating an affordable heat solution' (Setting 2).

Table 2. Contextualized agency options per issue

Agency options	Examples	Energy poverty	Affordable heat solution
Means	*Human resources, Material resources,	Deployable	-
	*Financial resources	Deployable	-
Skills	Project management, Participation, Marketing	-	-
Knowledge	Sustainability, Transition theory, Well-being	-	-
Voice	Capabilities to change narratives	Deployable	Deployable
Power	To direct actors, means and processes	Deployable	-
Relations	To change and create policy, collaboration, solidarity and, coalitions	Deployable	Deployable

Within each of the settings, differences in agency options also occur with activities. For example, in the case of an unemployed man living in the Spijkerkwartier, Arnhem (Setting 1). He wanted to engage in fixing houses

concerning insulation to alleviate energy poverty in those households. However, when he started working for the social entrepreneur, he risked a cut in his social benefits, which is problematic for him. This showed that, on the one hand, the municipality incentivizes the social entrepreneur with a subsidy to support unemployed citizens to work, on the other, implementation of these energy poverty mitigation activities revealed that unemployed citizens lost accrued rights to social benefits if they worked for the social entrepreneur. Thus, although the municipality executed their agency by starting the experiment, they were unable to prevent negative consequences for the participating citizens, despite it being specifically set up for them.

3.3 Agency options and changing collaboration

With activities in both learning-projects, actors encountered barriers that led to disruptive delays in the neighbourhood approach. For example, starting the implementation of the energy poverty approach in Setting 1, actors from outside the organization and municipal officials experienced insufficient mutual trust in the collaboration. This was identified as the main obstacle and could, fortunately, be addressed. During this process of collective reflection, the insight emerged that collaboration between the department responsible for social benefits and the executive municipal organization was problematic and that tasks, ambitions, interests, and ideas, were not aligned.

All participants experienced conflicting interests within the system. Upon repeated and deepening discussion of this issue in project meetings with policymakers from the municipality, changes within the municipal organization started to emerge. Growing awareness of mismatches between system panels, not only by the civil servants engaged in energy poverty but broader in the municipality, showed early signs of organisational culture change. One policymaker involved in AAEP stated: ‘One year ago energy poverty was not an important issue and few people within [our organisation] knew we were working on this. Nowadays everybody within the municipality knows how to find us.' Furthermore, structural changes became visible, and various intra-organisational meetings on energy poverty were held.

In working towards an affordable heating solution in Setting 2, a commercial actor and the municipality could not reach a consensus on financial requirements for the project. As a result, meetings focused primarily on the financial aspects and the interests of this particular market actor. Therefore, the experiment with the ambition to realize an affordable heating solution for residents narrowed down to pursuing a healthy business case. Despite the experimental nature of the process and the intention to learn, the commercial actor eventually withdrew from the process.

Both these and many more, examples concern obstacles in the process of collaboration with actors from other departments and external parties. This underscores the collaborative nature of addressing challenges in the ET and the need to leverage available agency options in the process as well, in addition to searching for new options. Thus, the realization of the ET may also be helped by employing agency in facilitating the process of collaboration between actors.

4. Discussion

4.1 Shifting agency position

The two settings clearly reveal differences in the deployment of the municipality's options to shape and execute their agency. Pesch (2015) distinguishes 3 types of agency options available to actors: appropriate resources, institutional power, and democratic legitimacy. Although the total resources of the municipality do not change, the impact of agency options may fundamentally differ depending on the contextual issue. For example, the available means, power and knowledge of municipalities may be sufficient to experiment with insulation work for job seekers in the energy poverty learning-project. However, the same capacities and resources are insufficient to play a decisive role in creating an affordable heat supply in the neighbourhood, where crucial stakes and power positions of the heat market lie with other actors. The position of the municipality in the market transformation (Loorbach et al., 2017; Nijhof et al., 2022) seems to

be a key factor. The municipality may be a key actor in energy poverty or neighbourhood safety, it is only a peripheral actor in the energy or heat market and the construction industry. Therefore, municipal agency options hinge on the role granted in the institutional playing field. In this study, we propose a preliminary model that can distinguish the deployment of agency options between activities within transformative issues. In Setting 1 the municipality utilized the agency options for Human and Financial resources and Relations, as various actors were put to work, and were mobilized to enable this. However, insight in the lack of Power, Skills and Knowledge, by the municipality actors revealed serious limitations, because policy frameworks and regulations did not allow for changing the structural conditions for problems such as the unemployed man. For Voice, there was a mixed picture, as options to enable voice of the group and of individual actors were present, but this interacts with stringent hierarchic policymaking from political actors in the Municipality.

4.2 Agency options and transformative change

Our findings suggest a relation between agency options and changes in collaborative processes, in other words, the inevitable systemic transformative changes (Loorbach et al., 2017). Hence, municipalities could deploy their agency options to achieve such transformative changes. At the same time, the actual agency of the municipality is bounded by those same systems. This resonates with the duality in which people's agency creates structures and those structures determine people's agency (Giddens, 1984). Our findings suggest that consciously using available agency options may be more productive than focusing on obtaining agency options currently unavailable.

5. Conclusion

Our preliminary conclusion based on this study has multiple layers. First, the degree of effective agency of municipalities varies across situations. Particularly, the options that municipalities have to influence situations and actions of other actors differ per issue and activity. Secondly, this shifting agency position is partly due to the varying leverage of agency options according to situational contexts. This applies to resources such as financial means and jobs, but also to knowledge and voice. Third, lack of agency often arises in relation to (inadequate or total lack of) collaboration.

This paper proposes a preliminary model for the options that shape agency of municipalities in societal transitions and contributes to the current understanding of transformational processes with the insight that agency is contextual and fluid and therefore may shift during transitional processes. Although resources may stay in place in an absolute sense, the degree to which they form effective agency options may vary per issue and activity. Variables observed to influence these shifts were the position of the actor in the regime or market, collaboration with other actors, the prevailing institutions, and the conscious focus with which the available agency options are deployed in situations where apparently required options are not available.

For municipalities as actors in transitions, this means that they should be aware that their role is not static and requires strategic planning that is responsive to contextual variables and events. Our insights suggest that the intended role of municipalities requires thoughtful use of agency options. Reflecting in advance on

which transformative change is at stake, and where it should lead, is necessary and consciously exploring in advance which agency options are available, offers a potential way of anticipating societal transitions ahead.

Acknowledgements

The authors would like to thank all participants of the learning-projects and participants in a workshop on the Earth Systems Governance Conference 2023 at Radboud University for their contributions and insights. Research activities for Setting 1 were funded by the Municipality of Arnhem, and those for Setting 2 by SIA RAAK for the project "Arnhem Learning Approach".

References

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.

https://doi.org/10.1191/1478088706qp063oa

De Roeck, F., & Van Poeck, K. (2023). Agency in action: Towards a transactional approach for analyzing agency in

sustainability transitions. Environmental Innovation and Societal Transitions, 48.

https://doi.org/10.1016/j.eist.2023.100757

Fischer, L. B., & Newig, J. (2016). Importance of actors and agency in sustainability transitions: A systematic exploration of the

literature. In Sustainability (Switzerland) (Vol. 8, Issue 5). MDPI. https://doi.org/10.3390/su8050476

Lee, B., & Saunders, M. N. K. (2017). Conducting Case Study Research for Business and Management Students. SAGE

Publications Ltd. https://doi.org/10.4135/9781529716702

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Loorbach et al 2017 Sustainability Transitions Research Transforming

Science and Practice for Societal Change. Annual Review of Environment and Recources, 45, 599–626.

Middlemiss, L., Stevens, M., Ambrosio-Albalá, P., Pellicer-Sifres, V., & van Grieken, A. (2023). How do interventions for energy

poverty and health work? Energy Policy, 180. https://doi.org/10.1016/j.enpol.2023.113684

Nijhof, A., Wins, A., Argyrou, A., & Chevrollier, N. (2022). Sustainable market transformation: A refined framework for

analyzing causal loops in transitions to sustainability. Environmental Innovation and Societal Transitions, 42, 352–361.

https://doi.org/10.1016/j.eist.2022.01.010

Pesch, U. (2015). Tracing discursive space: Agency and change in sustainability transitions. Technological Forecasting and

Social Change, 90(PB), 379–388. https://doi.org/10.1016/j.techfore.2014.05.009

Rijksoverheid et al. (2019). Klimaatakkoord. https://www.klimaatakkoord.nl/

Siggelkow, N. (2007). PERSUASION WITH CASE STUDIES. Academy of Management Journal, 50(1), 20–24.

Termeer, C. J. A. M., & Metze, T. A. P. (2019). More than peanuts: Transformation towards a circular economy through a small-wins governance framework. Journal of Cleaner Production, 240. https://doi.org/10.1016/j.jclepro.2019.118272

Uyterlinde, M., & Can, E. (2023). Wijken verduurzamen in turbulente tijden.

Uyterlinde, M., Van Hal, A., Coen, M., & Can, E. (2022). Samen naar een duurzame wijk.

2 Adaptive & regenerative built environment: **Conference paper**

Understanding Window and Door Opening Behavior in Dutch Social Housing for Digital Twins. A Study on Modelling occupants behaviour with machine learning.

Olivia Guerra-Santin[1]*, Luyi Xu[1], Sjoerd Offringa[1], Sara Willems[2]

[1] Department of the Built Environment, Eindhoven University of Technology, The Netherlands

[2] KU Leuven, Dept. of Civil Engineering, Building Physics and Sustainable Design, Belgium

* Corresponding author: Olivia Guerra-Santin (o.guerra.santin@tue.nl)

Abstract: This paper shows the results of the modeling of windows and doors opening behaviour in social housing in the Netherlands. Three dwellings were monitored for a full year before their renovation. The data was analyzed with machine learning to determine the drivers for opening windows and doors of the different households, and to build prediction models for their inclusion on a digital twin. The results show that the drivers for opening windows behaviour are different in the three different households, while door opening behaviour is mostly influenced by the location of the door. The prediction models for the three different dwellings show different levels of reliability. Although all models show good accuracy and precision, the recall of the models was lower in one household, showing that in some households, opening window behaviour might be also influenced by factors not related to indoor parameters, outdoor parameters or seasonal and daily patterns.

Keywords: occupants behaviour, windows and doors, renovation, social housing, modelling

1. Introduction

Buildings contribute to around 36% of the European energy consumption (IEA, 2020). Housing renovation is seen as an important aspect in the efforts to achieve carbon neutrality by 2050 as well as the energy transition (Directive (EU) 2018/844). Building performance simulations are often used during the design phase of buildings that will be renovated to determine the most effective renovation strategy for a specific building (type) or household. These simulations enable determining the most cost effective renovation strategy according to the technology payback periods, building characteristics, and households needs and requirements, and therefore could help to increase renovation rates.

While energy efficiency is often seen as the most important goal of building renovation, other building performance indicators, such as indoor environmental quality and occupants' satisfaction, are equally important, since they do not only contribute to the occupants wellbeing, but can also indirectly (and negatively) affect energy efficiency. The recognition of the effect of occupants' behaviour in building simulation, and therefore, on the performance gap, can be clearly seen in the amount of research carried out around this topic (Mahdavi et al., 2017; Hong et al., 2015). The performance gap is defined as the difference between the expected (designed) and actual (measured) performance of buildings. Methods to model occupancy, use of heating and cooling systems, natural and mechanical ventilation have been previously researched (Hong et al., 2016; Mossallam et al, 2023).

One of the most influencing factors on building simulations is the air changes per hour (achieved through both mechanical and natural ventilation). According to Cuerda (2020), natural ventilation is one of the most influential parameters in building simulations, therefore contributing the most to the performance gap. One of the reasons for this is that opening windows is very difficult to predict, and not enough data is available to make good models. Data on window and door operation is usually collected through diaries or questionnaires but there are doubts on whether this information is reliable. However, building monitoring is becoming more common and therefore, more data is becoming available which opens new possibilities. A number of research papers have focused on understanding window opening behaviour (Verbruggen, 2021), and to modelling window behaviour through different analytic methods (see Xu et al, 2022 and Schweiker et al., 2019 for an overview of papers).

In this research we focus on the possibilities to build natural ventilation models to be used as input parameters in a digital twin model of social housing in the Netherlands. Digital Twin is defined as a virtual representation of an object or system designed to accurately reflect a physical object, usually requiring the availability of real-time data. The objective of these models and digital twins is to define better renovation strategies for dwellings, in which both building characteristics and household characteristics are taken into account.

The aim of this paper is to determine what are the drivers of window and door opening behaviour, and whether we can predict it based on indoor and outdoor parameters, as well as contextual information. Furthermore, the objective of this research is to determine whether window and door operation can be modelled with building monitoring data.

Our objective is to develop individual window and door operation models that can be applied to the specific investigated building. We do not intend to generalize the model to all similar types of dwellings or households. Thus, in this paper we focus on the application of monitoring data and machine learning to generate these models, which could be applied to other monitored dwellings.

2. Methods

In this research we focus on a social housing project within the IEBB project. Three terraced dwellings have been monitored for a year before their renovation.

The sensors installed, include among others, indoor environmental quality and switch sensors to determine the operation of windows and doors.

The case study is located in the Dutch province Overijssel. The dwellings were built within the period 1946-1980. Before the renovation, they had an average insulation level, boiler, central heating with radiators, and mechanical ventilation exhaust. Figure 1 shows the layout of the dwellings, and the location of sensors.

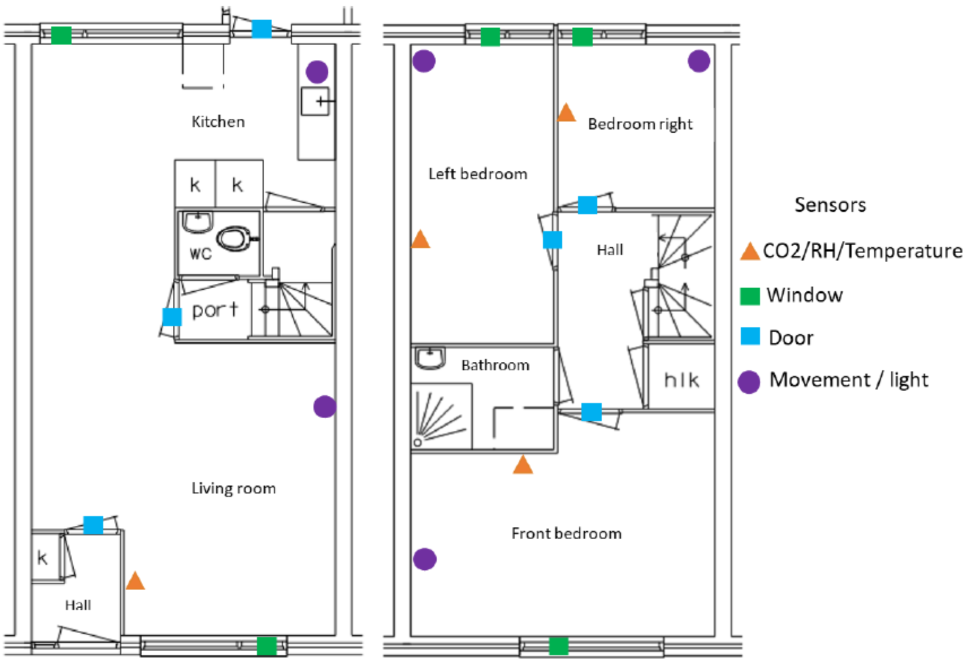


Figure 1. Floor plan and sensors locations

2.1 Data collection and availability

The data was collected from December 2021 to November 2022. The measurement frequency of indoor parameters was done per minute, while doors and windows operation (opening/closing) was recorded on action. Table 1 shows the type of sensors installed per room, and the data availability per sensor (sensors in bold correspond to 12 months data, the others are indicated).

Table 1. Data collected per room

	HKJH	QIMU	WEJH
Bedroom front	Window **Door** **CO2/temperature/RH** **Light/movement**	Window (11 months) **Door** **CO2/temperature/RH** **Light/movement**	**Window** **Door** ~~CO2/temperature/RH~~ **Light/movement**
Bedroom left	**Window** **Door** **CO2/temperature/RH** **Light/movement**	Window (6 months) **Door** **CO2/temperature/RH** **Light/movement**	**Window** **Door** **CO2/temperature/RH** **Light/movement**
Bedroom right	**Window** **Door** **CO2/temperature/RH** **Light/movement**	Window (6 months) **Door** **CO2/temperature/RH** **Light/movement**	**Window** **Door** **CO2/temperature/RH** Light/movement (6 months)
Living room	**Window front** Window back (5 months) **Door to hall**	Window front (9 months) **Window back**	Window front (8 months) Window back (4 months) **Door to hall**
	Door to Storage **Door to staircase** **CO2/temperature/RH** **Light/movement**	**Door to hall** **Door to Storage** **Door to staircase** **CO2/temperature/RH** **Light/movement**	**Door to Storage** **Door to staircase** **CO2/temperature/RH** **Light/movement**

Outdoor weather data was obtained from the KNMI meteorological station located in Heino, which was chosen based on the proximity to the site (less than 20km), as well as based on the observation of temperature and windspeed. The obtained outdoor parameters were: wind direction, wind speed, wind gust, temperature, sunshine duration, global radiation, rain duration, precipitation, and relative humidity.

2.2 Data pre-processing

Based on the location of the sensors in the dwellings, and on window and door data availability, it was chosen to first exclude all rooms except the bedrooms and living room from the analysis. Further analysis will be based on these selections.

Given that previous research has shown the strong connection between activities and habits and the opening of doors and windows, two additional variables were created: day of the year (Dayofyear) with values from 1 to 365, and minute of the day (Minuteofday) with values from 1 to 1440.

3. Results and analysis

3.1 Exploratory Analysis

Table 2 shows the percentage of time with windows open per dwelling per month. In average, the percentage of time with windows opened is comparable in the dwellings, the lowest (QIMU) with 16.2% and the highest (HKJH) with 20.7%. However, the figure shows very different ventilation patterns in the dwellings. Household HKJH seems to ventilate more than 50% of the time during the main summer months (July and August), and around 25-30% in the early and late summer months (June and September). In contrast household HKJH ventilates little the rest of the year. The trend in this household seems to be ventilating more with the weather, except in January, when they ventilated more than in December and February. In dwelling WEJH, as much natural ventilation is observed in the winter months (December and January) as in summer (June-August). In this household the months with less ventilation are during the spring (April and May) and November. In dwelling QIMU, more natural ventilation is observed in Spring than in Summer. The months with least ventilation are those in the late winter (January and February) and early autumn (September, October), but in November and December windows are open as often as in march and July. This leads to believe that not only weather and indoor conditions influence the operation of windows.

Table 2. Percentage of time windows are opened per month

House	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
HKJH	0.3	11.6	1.0	3.6	3.4	13.1	25.4	51.7	67.4	31.4	8.4	1.6
WEJH	24.3	35.9	15.3	10.2	2.9	5.9	31.7	19.0	26.5	10.6	14.8	7.9
QIMU	19.5	2.5	3.1	15.8	37.5	37.5	27.6	16.3	25.4	5.3	4.0	13.0
Av.	14.7	16.7	6.5	9.9	14.6	18.8	28.2	29.0	39.8	15.8	9.1	7.5

In the case of doors (Table 3), we can still see variation per month within a dwelling, with household HKJH keeping doors open longer time in the winter and summer; dwelling WEJH keeping the doors open longer time in the summer but in general a longer time in all months; and household QIMU keeping door open a longer time in the summer.

Table 3. Percentage of time doors are opened per month

House	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
HKJH	38.5	26.1	26.1	16.8	26.5	15.1	23.9	31.7	27.8	16.7	16.3	11.0
WEJH	35.9	33.8	32.1	36.9	26.4	37.3	53.2	49.4	22.7	38.2	40.9	18.4
QIMU	13.9	13.6	12.5	13.4	15.5	23.4	23.3	27.0	21.8	10.1	16.0	13.8
Av.	29.4	24.5	23.6	22.4	22.8	25.3	33.5	36.0	24.1	21.7	24.4	14.4

In general, window opening was more season-dependent than door opening. This suggests doors are used less for ventilation purposes. There was also a notable difference between households in door opening variance between seasons. This suggests some households use doors for ventilation purposes, whereas others do not.

Table 4 shows the average duration in hours of the windows and doors being open, and the percentage of actions lasting shorter than 5 minutes. In average household HKJH tends to keep some windows open for a whole day, while for WEJH and QIMU it is 13-15 hours respectively. In dwellings HKJH and WEJH, about 12.5% windows are open less than 5 minutes, while this is only 2.3% in QIMU. In table 5 we can also see that most of the actions regarding opening doors, last less than 5 minutes, meaning that these actions are more related to entering and exiting a room, that for internal ventilation.

Table 4 Average duration of windows and doors being opened and percentage of event lasting less that 5 minutes

Ventilator	House	Average duration in hours	5 minutes or less
Window	HKJH	25.8	12.8%
	QIMU	15.0	2.3%
	WEJH	13.0	12.2%
Door	HKJH	0.9	80.1%
	QIMU	0.8	69.9%
	WEJH	1.6	76.9%

Figure 2 shows the distributions of opening time and closing time of windows and doors per dwelling. The windows graphs show that household HKJH opens windows mostly on two times of the day, mid-morning and in the evening. WEJH household does the same but in minor degree in the evening, while QIMU household mostly does it in the morning. For doors the figure shows that in most instances, the door is closed shortly after it is opened.

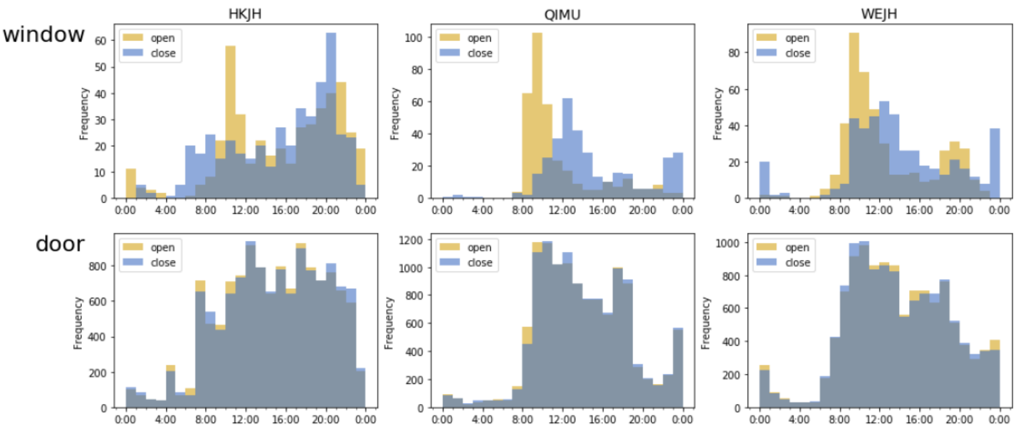


Figure 2 Opening and closing time of windows and doors (*Note that the darker color indicates overlap between both distributions)

3.2 Windows and doors opening models

In this section, a separate analysis is done for each house, and for both door and window as dependent variable. For the feature selection, in addition to the sensor features included in Table 1 (CO2, temperature, humidity, light and movement), three weather features with the highest correlation with the target variable (i.e. window or door) were included. This was done because of the large number of weather variables and the large correlation among them. Furthermore, in order to account for multicollinearity among weather and sensor features, all intercorrelations were computed and if an intercorrelation exceeded +/-0.5, the feature with the lowest correlation with the target was removed. Furthermore, features with a low correlation with the target variable (<0.05) were removed. Extra features were included related to day of year, minute of day, and room.

The dataset split ratio for training and testing were set to 75% and 25% respectively: The test size was set to 25% due to an abundance of data to train on. The data was split on a day base. This meant that every fourth day was included in the test set. This was done to prevent overfitting, which occurred with random sampling when complex models would know the door/window status of a data point in the test set based on data points from the train set that were close in time, for example 5 minutes before or after the data point in the test set.

3.2.1 Overview of the models

Baseline: A baseline model was created that only predicts the most common window/door status (which is always closed). This creates a reference point to evaluate the value of the other, more complex models.

Decision Tree: A Decision Tree classifier has a low complexity and is able to generate useful insights. It was created with a maximum depth equal to 3, which means the data is split into 2 groups 3 times. The division is based on features (e.g. indoor temperature, CO2 level, etc.) and results in an optimal separation of the outcome into variable classes (i.e., window/door status).

Random Forest: A Random Forest is an ensemble of decision trees. It has an increased complexity, but also shows an increased performance. It was created with a max. depth = 10 and number of trees = 20. This means 20 different decision trees are created and the most common outcome of these trees is used as prediction.

3.2.2 Overview of metrics

The following metrics are used to determine the fit of the model:

Accuracy shows how often a classification ML model is correct overall. This is the percentage of cases predicted correctly out of all cases. Recall shows whether an ML model can find all objects of the target class. This is the percentage of open window/door cases predicted correctly out of all open window/door predictions. Precision shows how often an ML model is correct when predicting the target class. This is the percentage of open window/door cases predicted correctly out of all actual open window/door cases.

The prediction was done for the full year, and seasonally, to determine whether yearly or seasonal models are more accurate in their prediction. Tables 5 and 6 shows the results of the models for windows and doors respectively. The tables show the baseline model (all windows/doors are predicted as closed), the decision tree classifier and the random forest. For all dwellings, the random forest is better at predicting the status of the windows and doors than the decision tree classifier.

The results show that a better model for windows has been obtained for the dwelling HKJH (Accuracy 95%, Recall 76.7%, Precision 89%), than for the other dwellings (QIMU 92.2%, 64.1%, 80.5% and WEJH 94.3%, 37.3%, 87.5%). In the case of doors, there are only very small differences between the models with all rooms and the models with only bedrooms and living room. For doors, the model for dwelling WEJH, the recall is better than the models of the other two dwellings (WEJH 84.3% vs HKJH 67.2% and QIMU 60%). There might be several reasons for the differences on recall for the models, which is the metric with a relative large difference (accuracy and precision remain close to each other). Lower percentage of recall indicates that not all episodes of open windows/doors are predicted. Therefore, there might be that the trigger to open doors or windows in household WEJH, and to a lesser degree on household QIMU are more random, or are caused by specific causes that are not recorded with the data, for example, opening windows or door for a specific activity that does not have an effect on indoor parameters.

The results from the random forest models are shown in the confusion matrix in Figure 3a-c. The matrix shows the number of correct predictions for the window/door being closed (predicted class =0 and true class = 0) and the correct predictions for the windows/door being open (and predicted class 1 and true class = 1), as well as the number of wrong predictions made by the model. In most of the cases, the models developed were able to predict most of the votes accurately with a reasonable margin of error, although better models resulted from dwellings HKJH and QIMU, than from WEJH.

Figures 4 and 5 show the feature importance for the random forest models, for both windows and doors. From them we can infer what features were more important per model. Opening windows is influenced mostly by the season (dayofyear) in all dwellings. CO_2 level also has a large influence in two dwellings (HKJH and WEJH), while dwelling QIMU is also largely influence by the location of the window (room_cat). Window location is also affecting the opening of windows in the other dwellings but to a lesser extent. Other common important parameters are indoor temperature, light, and time of the day. This indicates that while in all dwellings the season is very important for opening windows, in some dwellings air quality is a larger predictor, while in the third, the largest predictor is the location of the window, indicating that habits and preferences might be taking a more prominent role on the reasons for opening windows.

The opening of doors seems to be mostly determined by the location of the door (room_cat) for all dwellings, and followed by day of the year. Less important features were indoor conditions (HKJH), outdoor temperature and indoor conditions (QIMU, WEJH), and time of the day. This indicates opening doors is determined mostly by the room and season.

Table 5. Windows models – all year data

Windows		**HKJH**	**QIMU**	**WEJH**
Baseline	Accuracy	79,66	83,71	92,48
Decision tree classifier	Accuracy	91,5	90,79	92,98
	Recall	66,9	48,75	19,66
	Precision	78,98	83,09	84,84
Random forest	Accuracy	**94,97**	**92,23**	**94,31**
	Recall	**79,66**	**64,1**	**37,33**
	Precision	**89,07**	**80,5**	**87,53**

Table 6. Door models – all year data

Doors		**HKJH**	**QIMU**	**WEJH**
Baseline	Accuracy	76,97	82,84	70,46
Decision tree classifier	Accuracy	85,86	87,92	83,56
	Recall	56,82	53,31	85,74
	Precision	70,98	65,55	66,11
Random forest	Accuracy	88,51	90,06	88,87
	Recall	67,15	59,97	84,33
	Precision	76,1	78,08	78,01

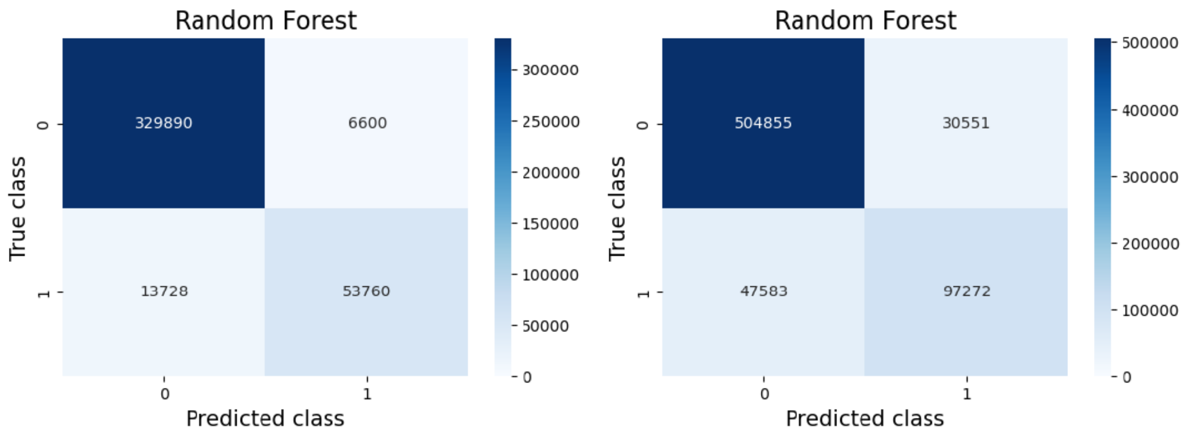


Figure 3a. HKJH Confusion matrix windows (left) and door (right)

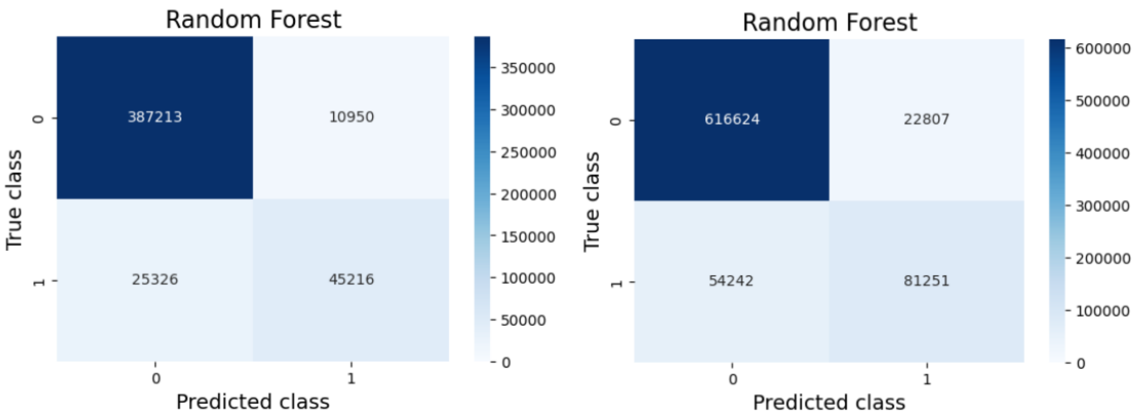


Figure 3b. QIMU Confusion matrix windows (left) and door (right)

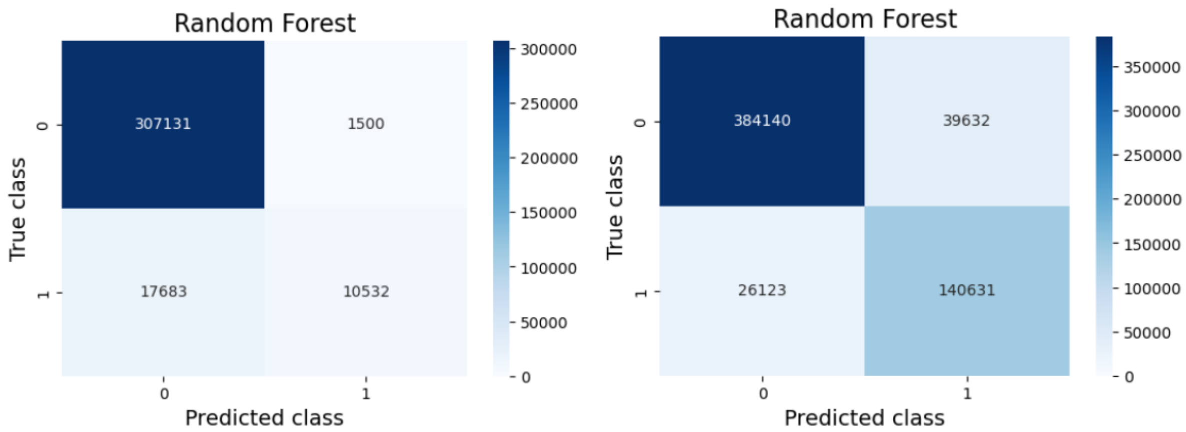


Figure 3c. WEJH Confusion matrix windows (left) and door (right)

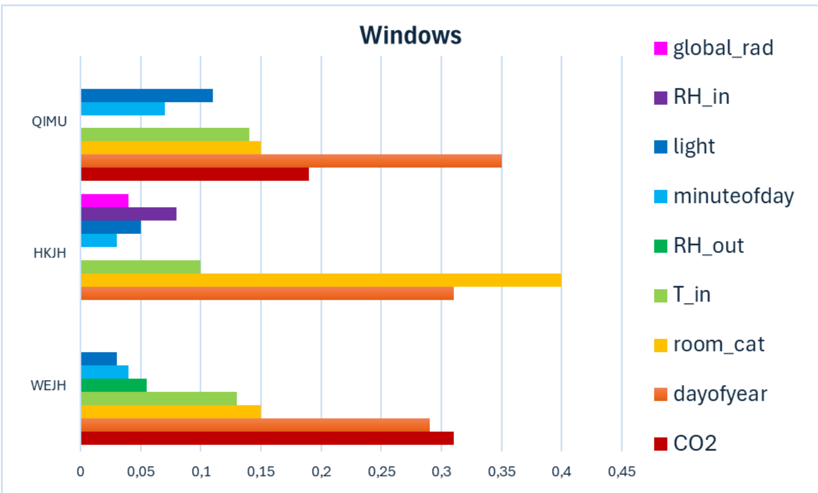


Figure 4. Feature importance - windows

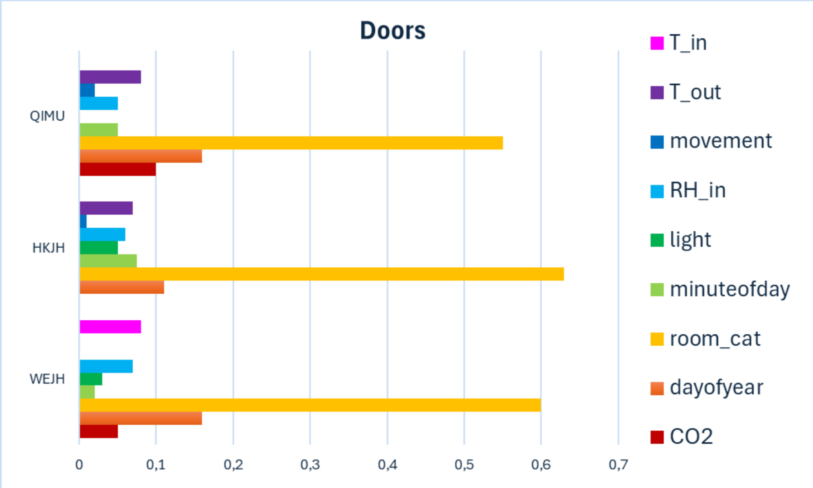


Figure 5. Feature importance - doors

4. Discussion

The results of the analysis showed that the prediction models for the three households were better at predicting the status of doors and windows in comparison with a baseline considering all windows and doors closed. While in all models, the accuracy and precision for both doors and windows were high and mostly similar in all dwellings, the recall was slightly different according to the dwelling. The model with higher recall for windows was for dwellings HKJH (80%), followed by QIMU (64.1%) and WEJH (37.3%). In regards to doors, the highest recall is seen in WEJH (84.3%), followed by HKJH (67.2%) and QIMU (60%). These results indicate that in some dwellings, the triggers for opening windows (WEJH) and doors (QIMU) cannot be explained with the data gathered because they are either too random (e.g. doors open according to random activities taking place in the room), or caused by a not monitored factor (e.g. VOC).

In section 3.1, the descriptive statistics showed the percentage of windows and doors open per month in the three dwellings. In all dwellings, windows are more often open in summer and less in winter. This is in line with the feature importance showed in Figure 4 (dayofyear, temperature). However, in dwelling WEJH, windows are also often open in the winter, which is reflected by the importance of the location of the window (room category) in this dwelling. This means that some windows are open frequently during the winter in this dwellings. On the other hand, the frequency of doors open are more or less persistent in all dwellings along the year. This is reflected in the lower importance of day of the year in comparison to the location of the door (room category).

5. Conclusion

In this paper, we aimed to determine the drivers that influence the opening windows and doors in social housing in the Netherlands. Furthermore, we sought to develop predicting models for the opening of doors and windows that can be used as input for digital twins or other types of building models. The following conclusions were drawn:

- Prediction results showed significant improvement over the baseline model (predicting all windows/doors as closed) and in all cases; the added complexity of the random forest model increased performance over the decision tree model.
- CO2 was an important feature for predicting window status of 2 houses, because a low CO2 level often results from an open window. Whether windows are open due to a high CO2 level or whether low CO2 levels are simply correlated with opened windows, is not clear in the model. However, this can be an indication of window opening depending on the presence of people, while the absence of this correlations indicates that windows are opened for other reasons than thermal comfort or air quality, and are instead caused by habits and schedules.
- Door location (room category) was the most important feature for predicting door status of all houses, indicating that there are specific doors in the dwellings that are kept open, while others are kept closed.
- Dayofyear was the most important or second to most important feature for predicting window and door status for all houses. This was also true for the seasonal predictions. This indicates that window and door opening vary according to the season. For example, bot, windows and internal doors are left open more often during warmer seasons.
- Light and movement sensors had little importance in predicting window or door status, since these factors might affect the moment when windows or doors are opened, but not the moments when the doors and windows remain open.
- Weather features had little importance in comparison to indoor parameters or time of the year and season.

In general, we can conclude that the models for opening of windows and doors might be highly dependent on individual household types. A model for opening windows and doors cannot be generalized to all households. Furthermore, although the results show that these actions depend highly on specific lifestyle and preferences of people, as well as on indoor conditions, the individual influence of these variables are very dependent on the specific household.

For Digital twins or other applications where monitored data is collected (for example in simulations carried out before renovation, or for building control and management) a specific household model could be built to define input data for the models. This will allow to make more accurate predictions when they are needed. This means that the presence of environmental sensors would be increasingly more necessary in buildings, implying extra costs for their installation and maintenance. However, we have already seen a similar trend in regards to smart meters, which are nowadays more common in both domestic and non-domestic buildings. Furthermore, the presence of indoor environmental sensors is also becoming increasingly important in the operation of buildings, since they can provide timely information regarding indoor environmental quality, which can be used to control better the HVAC systems in buildings, for example CO2-controlled mechanical ventilation systems.

Acknowledgements

This project is executed with the support of the MMIP 3 & 4 grant from the Netherlands Ministry of Economic Affairs & Climate Policy as well as the Ministry of the Interior and Kingdom Relations. This project has also received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037080 and from the Research Foundation Flanders (FWO), application number V426424N.

References

Cuerda, E., Guerra-Santin, O., Sendra, J. J., & Neila, F. J. (2020). Understanding the performance gap in energy retrofitting: Measured input data for adjusting building simulation models. Energy and buildings, 209, 109688.

European Parliament and Council of the European Union, "Directive (EU) 2018/844 of the European

Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency," 2018.

Hong, T., D'Oca, S., Turner, W. J. N. & Taylor-Lange, S. C. (2015). An ontology to represent energy-related

occupant behavior in buildings. Part I: Introduction to the DNAs framework," Building and Environment, 92, 764–777. doi: 10.1016/j.buildenv.2015.02.019.

Hong, T., Taylor-Lange, S. C., D'Oca, S., Yan, D. & Corgnati, S. P. (2019). Advances in research and applications of energy-related occupant behavior in buildings. Energy and Buildings, 116, 694–702. doi: https://doi.org/10.1016/j.enbuild.2015.11.052.

IEA, "World Energy Balances: Overview," Paris, France, 2020.

Mahdavi, A., Tahmasebi, F., Gunay, B., O'Brien, W. & D'Oca, S. (2017). Technical Report : Occupant Behavior Modeling Approaches and Evaluation.

Mossallam, B. E., Spiekman, M. & Hoes, L. (2022). Technical Report: Occupant models for use in hybrid building models. https://brains4buildings.org/wp-content/uploads/2023/06/B4B-WP3-D3.08-Occupant-models-for-use-in-hybrid-building-models_version1_final.pdf

Schweiker, M., Andersen, R. K., Berger, C., Carlucci, S., Chinazzo, G., & Edappilly, L. P., et al. (2019).

Dynamic review tables for topical reviews on occupants' perception and behaviour in buildings. Accessed April 2024. https://osf.io/gnvp2/?view_only=00b08233881f471795d1d8dee79e9828

Verbruggen, S., Delghust, M., Laverge, J., & Janssens, A. (2021). Habitual window opening behaviour in residential buildings. Energy and Buildings, 252, 111454.

Xu, L., Guerra-Santin, O., & Boess, S. U. (2022). Overview of occupant behaviour in modelling high

performance residential buildings. IOP Conference Series: Earth and Environmental Science, 1085(1), 012018. https://doi.org/10.1088/1755-1315/1085/1/012018.

2 Adaptive & regenerative built environment: **Conference paper**

Inclusive Built Environments: Integrating Social Sciences and User-Centric Approaches from three perspectives heritage, climate, and ageing.

Masi Mohammadi[1,2]*, Isabel Rodriguez Maribona[3], Beatriz Pineda[4], Agnieszka Kowalska[5], Joanna Syrda[5], Ignacio, Pedrosa[6]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[3] Technology TECU- Tecnalia, Spain

[4] RMIT Europe, Spain

[5] ASM Research Solutions Strategy, Poland

[6] CTIC Centro Tecnológico, Spain

* Corresponding author: Masi Mohammadi (m.mohammadi@tue.nl)

Abstract: The European construction and technology sector is at the forefront of developing technologically driven built environments, where a commitment to user-centricity is paramount. This commitment entails a meticulous alignment of developments with diverse social values, preferences, life course variations, and the full spectrum of end-user needs, effectively bridging theoretical constructs with practical realities to advance the sector.

This paper presents the results of an exploratory collaborative session that involved 42 experts from various interdisciplinary fields, providing diverse ideas shaping this broad sector. The session delved into the core of the sectoral transformation, emphasizing the necessity of human-centered approaches within the European built environment. The study advocates for the incorporation of human dimensions to effectively tackle societal challenges, namely ageing, sustainability, and the preservation of cultural heritage through digital innovation.

The working framework is designed to foster a multi-layered understanding of usercentric methodologies, analyzing engagement with end-users from the initial design concept to the implementation phase. This session explores the transformation of these insights into tangible design and implementation processes, illustrating the infusion of these insights into the industry's innovation cycle with real-life examples. Rigorous attention is devoted to ethical considerations, such as data usage, privacy, digital gaps, and the autonomy of individuals in the built environment. The session's multidimensional discourse covers three main areas: 1) Heritage, by examining the integration of usercentric approaches to uphold cultural integrity;

2) Climate in the Built Environment, by assessing user needs in the context of climate change and emphasizing well-being; and 3) Healthy Living, by making places that meet the social demands of users, addressing challenges such as ageing-in-place and utilizing insights from the built environment to fulfil both community and individual aspirations.
The findings underscore the sector's readiness to integrate user-centric approaches to enhance project outcomes and ensure sustainable and ethical development. This exploration sets the stage for more detailed future studies aimed at establishing frameworks for creating inclusive, adaptable, and resilient built environments that can better serve diverse communities.

Keywords: European Construction Technology, Human-Centered Design, Interdisciplinary Collaboration, Ethics in the built environment, User-Centric built environment

1. Introduction

The European construction and technology sector faces pivotal challenges crucial for its sustainable evolution, including heritage preservation, climate adaptation, and the growing needs of an ageing population. These complex challenges necessitate a shift from the traditionally efficiency-driven methods that have long dominated the sector to a more human-centered approach. Presently, the integration of human-centered design within the sector remains relatively underexplored, often overshadowed by a prevailing focus on technical and business development. This oversight underscores the urgent need for a paradigm that prioritizes both efficiency and the human and societal contexts in which these solutions are implemented.
Supporting this shift, literature advocates for a creative response to socio-material and socio-economic challenges through new human-centered design approaches that integrate ergonomics, psychology, and social sciences, ensuring that solutions are empathetic and inclusive of diverse human experiences (Auernhammer et al., 2022; European Commission, 2021). In response to this gap, this study leverages a dedicated session at the European Construction Technology Platform (ECTP) conference in 2024 as a critical forum for sector professionals and stakeholders from various fields. ECTP, comprised of over 150 member organizations spanning the construction sector and related industries across the Built Environment supply chain, provides a collaborative platform for advancing knowledge and practices in the industry. Experts engaged in the session were either members of ECTP or had established collaborations with the platform, ensuring a high level of expertise and relevance to the subject matter. The researchers involved in developing the paper come from diverse backgrounds in both human sciences and the built environment field. They are members of two Executive Board Committees of this European platform, specifically the 'Built for Life (B4L) Committee' and 'Heritage & Regeneration Committee.' As active participants in the projects

discussed in this paper, their involvement ensured that the selected projects directly align with the theme of human-centric built environments. The selection process for the four projects was based on their direct relevance to this theme.

These four real-life case studies, carried out across Europe, represent collaborative efforts across Europe and focus on heritage preservation, climate adaptation, and healthy living for an ageing population. They serve as compelling examples of the tangible impact of human-centered approaches in these critical areas, demonstrating innovative strategies and real-life applications.

1.1 Heritage Preservation

Heritage sites, particularly in rural areas, increasingly face threats from environmental changes and the pressures of tourism, which risk degrading their cultural significance and physical integrity. The EU-funded RescueME project (2023-2026) stands as a strategic response to these challenges, aiming to bolster social cohesion, local economies, and environmental sustainability while preserving cultural and natural heritage. The project specifically addresses the dual threats posed by climate change and tourism by equipping communities, especially in coastal areas, with the necessary tools and knowledge to safeguard their heritage (RescueME. (2023).).

Practically, RescueME innovates strategies that meld physical and digital tools to effectively manage and regulate tourist access, thereby preserving site integrity and public accessibility. It employs a co-creation methodology, engaging local stakeholders throughout the planning and implementation stages to ensure that solutions are culturally sensitive and driven by community needs. This method fosters resilience against climate-related disasters and tourism impacts across five cultural landscapes, utilizing Communities of Practices, workshops and surveys for iterative feedback and adaptation.

Ethically, the project addresses complex dilemmas such as balancing public access with conservation imperatives and ensuring access measures do not disproportionately benefit economically advantaged groups. This careful management of cultural landscapes is essential to maintaining the integrity of nonrenewable cultural resources while allowing citizens to enjoy and learn from these environments.

1.2 Climate Adaptation

The imperative to adapt the built environment to climate variations underscores the necessity for structures that minimize energy consumption and adapt to cultural and climatic differences across Europe. The Cultural-E and COMMUNITAS projects exemplify the sector's response in this area. Cultural-E develops modular and replicable solutions for Plus Energy Buildings (PEBs) that consider climate and cultural variances throughout Europe, employing advanced technologies such as active window systems, cloud HMS, smart air movement, and decentralized heat pumps tailored to specific energy needs and contexts (Cultural-E, 2024).

Communitas extends these efforts by directly engaging communities in energy production and consumption decisions, fostering sustainable energy practices through innovative community energy systems (Communitas, 2023). Both projects incorporate deep ethical considerations, particularly in terms of data privacy and the engagement of communities, ensuring that technological implementations are beneficial and do not undermine communal living.

Methodologically, Cultural-E utilizes diverse empirical methods to gauge how residents interact with new technologies, adjusting systems to better meet user needs. Similarly, COMMUNITAS employs participatory research methods to develop energy solutions that are equitable and specifically tailored to community needs, critically assessing Social Sciences and Humanities perspectives through various stages of engagement and development (Communitas, 2021).

1.3 Ageing

With a demographic shift towards an ageing population, the integration of assistive technologies into living environments to support the health and autonomy of older individuals, particularly in less accessible rural areas, has become increasingly crucial. The IBERUS Cervera Network of Excellence (https://www.iberushealth.org/) addresses this need by co-designing and developing discreet, video-based monitoring systems that enhance the quality of life, through safety and independence, of post-stroke patients, among others. This technology enables consistent, non-intrusive monitoring, particularly beneficial in areas where professional healthcare and familial support are limited (Lindberg & Lundgren, 2022; Moor & Mohammadi, 2020).

At the heart of the IBERUS project is an ethics-by-design approach that emphasizes user consent, data security, edge data processing, and minimal data usage to maintain privacy and autonomy. This approach carefully balances the need for safety monitoring with the imperative to respect personal privacy, ensuring that technological solutions enhance rather than compromise the dignity and independence of older individuals.

Despite the progress made by the CERVERA Network of Excellence in harmonizing technology with the living environments of older people, significant gaps remain, particularly concerning the long-term psychological impacts of such technologies on their well-being. Further research is needed to explore how continuous monitoring and interaction with these technologies affect older individuals' sense of independence and mental health, as well as the appropriate management of this information by healthcare professionals, highlighting the necessity for ongoing evaluation and adaptation of technological interventions.

2. Methods

This research utilized a collaborative session to explore and emphasize the added value of integrating social sciences and user-centric approaches in enhancing the effectiveness of the European construction and technology sector. The session convened 42 experts from diverse fields such as construction and infrastructure, heritage, architecture, urban planning, smart technology, and policy. All experts, either members of ECTP or with established collaborations with the platform, provided insights aimed at addressing sector-specific challenges, thus showcasing the practical implications of a human-centered methodology.

The session was designed to maximize productivity and facilitate holistic discussions. It commenced with an overview of how social sciences and user-centric approaches have been implemented in four real-life case studies across Europe, setting the context and objectives within three thematic areas: heritage preservation, climate adaptation, and accommodating the aging population. Each thematic segment was tailored to explore specific sector challenges, incorporating practical solutions, ethical considerations, and methodological rigor.

Practical analyses covered a spectrum of factors, including economic implications and user interactions with contemporary building technologies, assessed within broader environmental, cultural, and health objectives. Ethical aspects examined included security, privacy, the balance between the intrusiveness and autonomy of technologies, and the extent of civic engagement—each designed to ensure equitable and secure user experiences. Methodological rigor was enhanced by tools such as usability testing, user experience surveys, and behavioural analysis, while techniques like A/B testing and heatmaps further refined user interfaces within smart environments.

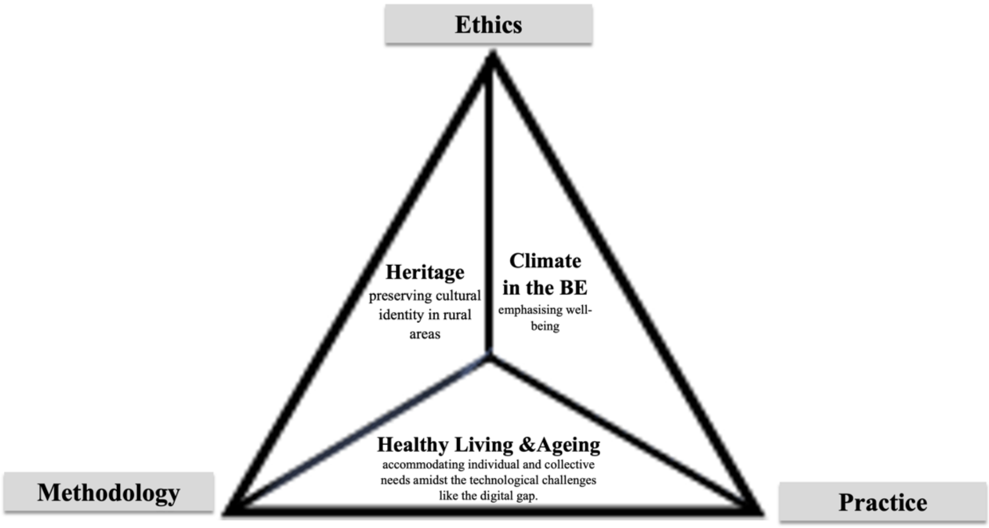
This collective exploration was channeled through a working framework to unify and analyze the diversity of the case studies, which varied widely in subject, focus, approach, and area within the built environment. This structured framework transcends the initial themes of heritage preservation, climate adaptation, and health, enhancing the analysis of integrated data across the built environment. Figure 1 visually abstracts this approach, merging the thematic areas with interrelated perspectives of practice, ethics, and methodology. Its holistic nature facilitates comparisons beyond these initial contexts, illustrating the framework's versatility in applying social sciences and humanities to diverse themes. This adaptability makes it an useful tool for exploring interconnections across various projects, promoting a broader, integrated approach to user-centric and socially responsible strategies within the built environment.

To ensure engaging and focused discussions, each presentation concluded with a question posed through Mentimeter, a real-time polling tool that enabled participants to contribute their thoughts and vote on specific topics. Ethnographic observations during the breakout sessions complemented the interactions, focusing particularly on capturing the dynamics between participants and highlighting engagement patterns.

These observations were instrumental in understanding the interactional nuances that informed our synthesis of findings.

The session concluded with a synthesis of the findings and insights gathered. This closing segment involved summarizing the key points and identifying emergent themes that are poised to inform future research and policy-making efforts, directly linking the methodological approach to the strategic goals of the sector.

Figure 1. Addressing human-centered challenges in the construction and technology sector through a holistic approach that integrates practical solutions, ethical considerations, and methodological discipline.



3. Results and analysis

The results from the collaborative session, which involved 42 multidisciplinary experts from the European construction and technology sector, were insightful and indicative of the potential for human-centered innovation and sustainable practices within the industry. The progression from the Mentimeter questions to the three interactive thematic segments allowed for an in-depth analysis of each theme. The participants' insights from the polls provided a starting point for subsequent discussions. This approach ensured that the results captured both the immediate feedback and the nuanced explorations of the participants, offering a multifaceted perspective on the challenges within the European construction and technology sector. It underscores the sector's commitment to advancing with innovations that are not only technically sound but also deeply considerate of the societal, cultural, and ethical dimensions.

Figure 2: An exploratory session involving experts from various interdisciplinary fields, offering diverse insights into the core of the sectoral transformation. This figure highlights the emphasis on the necessity of human-centered approaches within the European built environment.

3.1 Heritage Thematic Segment

The Mentimeter question for the Heritage subgroup focused on managing the conflict between public access and the protection of cultural landscapes, setting the tone for the breakout session. The responses were enlightening, with one participant noting, "We must shift from mere visitation to meaningful engagement," highlighting a nuanced understanding that the management of cultural heritage requires innovative approaches that transcend traditional methods. Another insightful comment from the session was, "Heritage is not just to be observed; it is to be experienced and understood," emphasizing the need for deeper, more immersive experiences that can alleviate physical strain on the sites. The subgroup explored diverse strategies such as, "Digital storytelling can not only tell the history but can preserve it," showcasing the pivot towards non-invasive yet enriching technological solutions.

With 35 participants providing input on this challenge, the interactive session then saw 10 participants delve deeper into how these initial suggestions could be implemented. The group discussed a range of innovative strategies that extended beyond the Mentimeter suggestions, such as virtual reality experiences to disperse tourist impact and educational programs to empower local communities in preserving cultural integrity. These detailed outcomes stressed the importance of a participatory approach in heritage conservation, which could lead to more effective and sustainable management of cultural sites. The heritage subgroup adopted a formal and structured approach using post-its and flipcharts to organize thoughts and facilitate equitable contributions. This group proposed several innovative strategies aimed at managing tourism flows in a way that balanced heritage preservation with visitor engagement. Strategies such as implementing digital provisions, virtual reality, and storytelling were discussed as methods to diversify tourist experiences, thereby reducing the physical strain on sites while enriching the narrative of heritage landscapes. An essential aspect of their discussion was the focus on educating local inhabitants about the importance of preserving their cultural assets, suggesting that community involvement is crucial in sustainable heritage management. This discussion illuminated the potential for multidisciplinary collaboration in creating sustainable and inclusive built environments that respect cultural integrity and address contemporary societal challenges from the design phase through to practical implementation.

Climate in the Built Environment Subgroup The Mentimeter for the Climate subgroup focused on the question, "What aspects should be taken into account to maximize energy efficiency while prioritizing residents' wellbeing?". Gathering 21 responses, the conversation brought to light a spectrum of considerations. These ranged from the Physical Environment— where the importance of "indoor air quality" and "thermal comfort" was stressed—to the Socio-cultural Framework, noting the need to reflect "cultural aspects" in energy solutions. Economic viability was also a key point, with participants indicating that Economic Aspects should not be overlooked when seeking sustainable practices. Notably, one participant suggested "use tools for human thermal model that allow to adjust to own comfort," emphasizing the necessity of personalizing energy-efficient design. This quote illustrates the session's consensus on the importance of aligning technical energy-saving measures with the individual's need for comfort—a user-centered approach that resonates through the subgroup's deliberations.

Further discussions explored the delicate balance between technical "energy parameters" and the more subjective "comfort parameters," underscoring a holistic view where energy efficiency and well-being are not mutually exclusive but rather complementary. The dialogue was rich and multi-faceted, covering the gamut from GDPR and data privacy concerns to the nuances of eco-fatigue. Ultimately, it centered on the intricate task of harmonizing energy efficiency with residents' well-being—a discourse that crystallized the need for solutions that respect cultural and demographic diversity. The group underscored the critical need for building solutions that support not only environmental sustainability but also the socio-cultural fabric of communities, advocating for a built environment that truly caters to all facets of sustainability.

3.2 Healthy Living and Ageing Thematic Segment

In the Healthy Living and Ageing segment, a Mentimeter poll posed the question, "Why is it important to address ethical challenges in user-centered construction?" drawing 18 responses that emphasized privacy and autonomy. A notable response was, "The home should be a sanctuary, not a surveillance state," reflecting a strong stance on maintaining dignity and respecting privacy with the use of smart technologies for older individuals. Further discussions reinforced the idea of technology as a supportive companion rather than a controlling entity, stressing the enhancement of personal autonomy rather than its diminution, where one participant remarked, "Technology should be a companion, not a controller," bringing to light the necessity for technology to enhance, not impede, personal autonomy. At this point, emphasis was also placed on the importance of involving not only the person aging but also their proxies and all those who can contribute to health and decision-making regarding their well-being.

Participants also explored the implications of technological integration for older individuals, focusing on maintaining human connections and addressing ethical and social concerns. The discussions extended to the potential risks of data misuse and/or secondary use of data and its implications for privacy and health insurance, underscoring the need for ethical standards that evolve with societal changes and the risk of depersonalizing individuals by solely analyzing data. The subgroup emphasized that technological advancements should be accessible to all, not just those who can afford them, to prevent widening the digital and social divide. A significant concern raised was the importance of ensuring social equity in access to these technologies.

Furthermore, the discussions underscored the necessity of tailoring technological solutions to individual needs, recognizing that each person has unique circumstances and requirements. This approach argues against a one-size-fits-all solution and advocates for the customization of technologies to enhance their usefulness and acceptance. Thus, highlighting the need of context understanding by involving the human along the whole process. The subgroup also discussed the evolving ethical landscape as technologically integrated generations age, emphasizing the need for adaptable and responsive ethical frameworks to accommodate shifting attitudes and changes social values, especially on younger population, towards privacy and technology use. The segment's discussions offered insights into integrating technology in environments for older people, not just focusing on technical aspects but also enhancing well-being, maintaining dignity, and promoting inclusiveness. These insights shed light on the multifaceted challenges and opportunities in employing technology to support ageing populations, reflecting a comprehensive understanding that will guide future research and policy-making efforts.

4. Discussion and conclusion

This session successfully united 42 specialists from a diverse array of disciplines within the European construction and technology sectors—ranging from construction and infrastructure to urban planning and policy. This blend of academic and industry expertise laid a solid foundation for the collaborative brainstorming sessions conducted. The session was divided into three thematic parts, each designed to deepen the integration of Social Sciences and Humanities to foster user-centric outcomes in construction. The focused explorations addressed three critical areas:

- Heritage: Participants discussed the dynamic nature of preservation, emphasizing not just the protection but the active facilitation of cultural vitality. Innovative, practical, ethical, and methodological frameworks were explored, particularly on preserving cultural identity in rural areas.

- Climate in the Built Environment: Discussions centered on the dual goals of sustainability and comfort, strategizing to mitigate energy poverty while prioritizing user-centric approaches amid climate change.
- Healthy Living and Ageing: This subgroup focused on creating adaptive environments for the ageing population, integrating emerging technology to cater to both individual and collective needs, thereby promoting inclusivity and ethical considerations.

Across all subgroups, there was a strong emphasis on interdisciplinary and user-centric solutions to address the sector's complex challenges. The discussions not only provided deep insights into each thematic area but also highlighted the interconnections between these domains, enhancing the overall understanding of the sector's dynamics.

The dialogue throughout the session was rich, demonstrating a solid commitment to ethical practices, innovative solutions, and sustainable development. This discussion underscored the sector's capacity to evolve and adapt to a human-centered global landscape, showing a proactive approach to integrating social sciences and user-centric methodologies that are likely to drive the sector towards more adaptive and responsive practices.

This collaborative effort reflected the diverse expertise present and aligned well with the broad goals of advancing the European construction and technology sector. The integration of social sciences and user-centric approaches effectively highlighted the practical effectiveness of these methodologies in real-world applications.

The holistic approach adopted during the session illuminated the complexities of integrating user-centric design principles within a rapidly advancing technological landscape. The detailed analyses provided by each thematic segment not only suggested a path forward but also emphasized the importance of ethical, practical, and methodological considerations in the development of user-centric strategies.

This session produced a theoretical and practical framework enriched with ethical guidance, offering actionable insights for the application of user-centric principles. The insights gained underscore the need for innovations that respect the balance between efficiency and human-centric values, advocating for the development of sustainable and inclusive environments that honour both historical values and contemporary societal needs.

Overall, the insights garnered from this session provide a valuable outline for future innovations, highlighting the necessity for solutions that are technically sound, culturally sensitive, and ethically grounded. This ensures their broad acceptance and practical utility, reinforcing the principles crucial for real-world applications aimed at enhancing the social fabric and environmental sustainability of European communities.

References

European Commission. (2021). The EU in 2021 - General Report on the Activities of the European Union. Retrieved from https://op.europa.eu/webpub/com/general-report-2021/en/

RescueME. (2023). Resilient cultural landscapes. Retrieved from https://resilientculturallandscapes.euAuernhammer, Jan & Zallio, Matteo & Domingo, Lawrence & Leifer, Larry. (2022). Facets of Human-centered Design: The Evolution of Designing by, with, and for People.

Johnson, B., Clarke, J. M. (2019). Collecting Sensitive Data: The Impact on Researchers. Qualitative Health Research, 13(3), 421-434. https://doi.org/10.1177/1049732302250340

Cultural-E Consortium. (2024). Cultural-E – Climate and cultural-based solutions for Plus Energy Buildings. Retrieved from https://www.cultural-e.eu

COMMUNITAS. (2023). Bound to accelerate the roll-out and expansion of Energy Communities and empower consumers as fully-fledged energy market players. Horizon Europe. https://communitasproject.eu/

IBERUS project. Technological Network of Biomedical Engineering Applied to Degenerative Pathologies of the Neuromusculoskeletal System in Clinical and Outpatient Settings (CER-20211003) and the CERVERA Network financed by the Ministry of Science and Innovation through the Center for Industrial Technological Development (CDTI), charged to the General State Budgets 2021 and the Recovery, Transformation, and Resilience Plan.

Lindberg, J., & Lundgren, A. S. (2022). The affective atmosphere of rural life and digital healthcare: Understanding older persons' engagement in eHealth services. Journal of Rural Studies, 95, 77-85. https://doi.org/10.1016/j.jrurstud.2022.07.020

Moor, N., & Mohammadi, M. (2020). Grey Smart Societies: Supporting the Social Inclusion of Older

Adults by Smart Spatial Design. In Smart Cities and Connected Intelligence: Technologies, Platforms, and Applications (pp. 160-174). Springer. https://doi.org/10.1007/978-3-030-12180-8_8

2 Adaptive & regenerative built environment: **Abstract workshop**

Nieuwe prestatie-eisen voor wonen met zorg

Olga Görts-van de Pas[1*]

[1] Netwerk Conceptueel Bouwen, The Netherlands

* Corresponding author: Olga Görts-van de Pas (olga@netwerkconceptueelbouwen.nl)

De vraag naar woningen waarin ouderen comfortabel kunnen wonen en waar passende zorg verleend kan worden is groot.

Het Netwerk Conceptueel Bouwen is een kennisnetwerk en heeft als missie partijen werkzaam in de woningbouwmarkt bij elkaar te brengen om conceptueel bouwen te stimuleren. Daarvoor ontwikkelde het NCB onder andere De Woonstandaard waarin veelgevraagde productmarktcombinaties (PMC's) zijn gedefinieerd. Samen met Actiz, Aedes, en de ministeries van BZK en VWS werkt het Netwerk Conceptueel Bouwen aan het definiëren van nieuwe PMC's voor levensloopbestendige woningen, geclusterde woonvormen en verpleegzorgplaatsen. Met deze prestatie-eisen breiden we De Woonstandaard uit.

We helpen hiermee opdrachtgevers bij het formuleren van de uitvraag voor nieuwbouw van zorggeschikt vastgoed en stellen conceptaanbieders in staat hun aanbod uit te breiden met deze producten voor wonen met zorg waardoor we sneller, slimmer en schoner kunnen bouwen voor een scherpe prijs/kwaliteit.

3

Healthy cities & nature-based living (with care) concepts

3 Healthy cities & nature-based living (with care) concepts: **Conference paper**

Strengthening the integration of health in urban spatial planning. Lessons learned from the development of a practical tool

Dorus Gevers[1*], Sandra Akkermans[2], Mare Knibbe[3], Marijn van de Weijer[4], Joop de Kraker[5]

[1] Department of Health Promotion, Research Institute of Nutrition and Translational Research in Metabolism (NUTRIM), Faculty of Health, Medicine and Life Sciences, Maastricht University Medical Centre+, The Netherlands

[2] Unit Medische Milieukunde, GGD Zuid Limburg, The Netherlands

[3] Department of Health Ethics and Society, CAPHRI, Maastricht University, The Netherlands

[4] Research Group Smart Urban ReDesign (SURD), Zuyd Hogeschool, The Netherlands

[5] Maastricht Sustainability Institute (MSI), Maastricht University, The Netherlands

* Corresponding author: Dorus Gevers (dorus.gevers@maastrichtuniversity.nl)

Abstract: The built environment is an important determinant of our health. Therefore, there is an urgent need for tools to support policy makers and spatial planners in creating a healthy built environment. We focused on the improvement of a tool (Check&Grow) designed for strengthening the integration of health in spatial planning, learning from two spatial development projects in Maastricht and Kerkrade (The Netherlands). Both projects concerned the development of an Integrated Child Center, including the surrounding area. We followed a three-step approach for tool improvement: i.e., joint problem diagnosis, co-designing improvements, and testing the improved tool by policy makers and urban designers. Through co-creation, two main improvements for the tool were proposed. The first improvement included recommendations regarding the collaboration process and the application of the tool. The second improvement included the proposal to connect health with other, more robust values in spatial planning such as climate adaptation. Finally, we recommend to further investigate the use of binding rules of thumb and standards for a healthy built environment.

Keywords: built environment, tool development, healthy cities, living lab, co-creation

1. Introduction

Increasingly, the environment is receiving attention in Dutch policy and practice as an important determinant of our health. Examples include The National Prevention Agreement and The Environment and Planning Act (Ministry of Health, 2018; Ministry of Infrastructure and Environment). As a result, health should be considered in all larger spatial developments. A healthy environment in this regard, can be defined as an environment in which the pressure on health is as low as possible, but also an environment that encourages healthy practices (e.g. physical activity, social interaction, recreation) (The Council for the Environment and Infrastructure, 2018). Where the first part of this definition refers to the protection of health, the latter implies health promotion.

RuimteGIDS, which is a Dutch acronym and stands for 'Making space for health in the city', started as a research consortium in 2018 with the development of a regional knowledge agenda (RuimteGIDS, 2018). The knowledge questions on this agenda were co-created by scientific researchers, policy makers, decision makers, and practitioners. Through Transdisciplinary Action Research (TAR), scientific researchers from several disciplines (including the authors) work together with policy, practice, and citizens to address the questions of the knowledge agenda. In so-called learning projects, there is an ongoing translation of research findings into practice in order to shape a healthy built environment.

Within two of the learning projects, research consortium RuimteGIDS was involved in the spatial planning process of Integrated Child Centres (ICCs), one in Maastricht and one in Kerkrade. An ICC is a local service for children aged 0 to 13 years old, covering childcare and primary education. ICCs are important public services in residential neighborhoods because here ideas, opinions and lifestyle behaviors of children and their caregivers are shaped – having a major impact on health (Sykes & Musterd 2011; Bikomeye, Balza, & Beyer (2021). RuimteGIDS participated in the planning process of both ICCs by applying a checklist for healthy spatial planning, which was based on existing tools and named Check&Grow. An overview of the themes and example criteria in the Check&Grow tool can be found in table 1. The learning cycles that were completed as part of the spatial planning process of the two ICCs, are examples of TAR as conducted by RuimteGIDS.

The results of a cross-case analysis of the ICC planning processes in Maastricht and Kerkrade show that health, as a value in urban planning, was not robust enough (Gevers et al., 2023). Despite participatory application of the Check&Grow tool and a written advice to the municipally about the healthy development of the Maastricht ICC surroundings (Gevers, Vonken, van de Weijer, Oosterbroek, Akkermans & Esser, 2021), health was not a priority during the design. Municipalities have to make complex decisions, considering not only the health impact of spatial planning projects, but also costs and benefits with respect to sustainability, biodiversity, safety and operational management.

Table 1: Overview of the themes and criteria in the Check&Grow tool (first version, 2021).

Theme	Example criterion
Physical Activity	An attractive streetscape and appealing design for pedestrians and cyclists (e.g., pleasant landscape, appropriate amenities and shelter from the weather).
Social interaction and inclusion	Resources to enable activities and events and encourage the development of neighborhood organizations
Social safety	Clarity for users for what and by whom the area can be used (private, public, or communal)
Working together towards a healthy built environment	Involvement of the local community in planning (in the design of the area, implementation of the plan, and management of the area). For example: All residents can participate (young and old, rich and poor, educated and uneducated). Active cooperation of organizations (such as municipality, healthcare institutions, welfare and housing corporation) with neighbourhood residents.

Considering the above, there is a need for a practical tool that contributes to making health a more robust value in spatial planning, while utilizing existing knowledge and considering the local context and citizens' perspectives. The aim of our project (RuimteGIDS Living Lab) was therefore to improve the Check&Grow tool in a way that it would make health a more robust value in spatial planning, thereby strengthening the integration of health.

2. Methodology

2.1 Study design

Due to the limited time span for this research project (8 months), it was not possible to improve and test the Check&Grow tool in the context of a real-life spatial development project. To compensate for the absence of real-life experimentation, we tested the improved tool in a policy workshop and an urban design workshop. Despite the fact that this test did not take place in a real-world setting, we prefer to use the term Living Lab for our approach, as the core elements of multi-actor co-creation and learning (Scholl & De Kraker, 2021) were present.

Figure 1, RuimteGIDS Living Lab partners discussing the methodology and progress in the primary school which had to be redeveloped (location Kerkrade).

2.2 Living Lab steps

RuimteGIDS Living Lab followed a three-step approach to improve the Check&Grow tool. The steps were conducted separately for the Maastricht and Kerkrade case.

Step 1: Joint problem diagnosis

Based on the involvement of RuimteGIDS in the spatial planning projects, we had some insights into the integration of health in the various phases of the spatial planning process and the effectiveness of the first version of the Check&Grow tool. These preliminary insights were based on individual interviews and informal conversations with policy makers and practitioners. In the first step of the Living Lab, we reconstructed the spatial planning process and deepened our initial understanding. The reconstruction covered the following aspects: stakeholders involved, responsibilities, finances, policies and rules, and the integration of health in the various phases of the planning process (ranging from exploration to maintenance). In a focus group session led by the scientific researchers, representatives from the municipality, education board, regional public health service and citizens jointly reflected on the preliminary insights.

Step 2: Co-designing improvements

In step 2, a co-design session took place in which the Living Lab participants together discussed possibilities for the improvement of the Check&Grow tool. The scientific researchers facilitated these sessions. After presenting the outcome of the problem diagnosis conducted in the focus group, two A0 posters were used to promote and structure discussion on possible improvements. A first poster included a schematic drawing of the Check&Grow tool. Post-its were provided to participants for suggesting ideas with respect to the tool itself (e.g., additional themes, form and lay out of the tool). A second poster (see figure 3) provided an overview of the spatial planning process, split up in phases ranging from exploration to maintenance, and supplemented with specific barriers for the integration of health as identified in step 1. This second poster was meant to elicit ideas related to the process of integrating health (e.g. parties to involve and roles they are supposed to take).

Step 3. Testing the improved tool by policy makers and urban designers

The improved Check&Grow tool and the proposed improvements for the spatial planning process were tested in a policy exercise workshop and in a design workshop by BA and MA level students in the fields of Built Environment, Architecture, Urbanism and Landscape Architecture. In the policy exercise workshop, each phase of a spatial planning process was discussed in relation to the improved tool with policy and decision makers, to determine if it would lead to a better integration of health as compared to the first version of the tool. Regarding the design workshop, 39 students in a one-week international design workshop implemented the Check&Grow tool in a spatial analysis and design process. The participants worked on fragments of two Maastricht neighbourhoods. The approach was to implement the Check&Grow tool both in the analysis phase and the design phase of the assignment. In the analysis phase, participants made inventories of the space occupied by housing, greenery, parking & infrastructure, and water retention. The figures were compared to several 'rules of thumb' for a healthy built environment, of which the 3-30-300 rule formulated by Konijnendijk (2021, 2023) proved the most prominent to determine the extent to which the neighbourhoods already comply with this rule. The 3-30-300 rule implies that from buildings, everyone should be able to see at least three mature trees, that each neighbourhood should have a 30% tree canopy cover, and that everyone should have a public green space within 300 meters from their homes available. In the second phase, participants defined a design agenda for improving the neighbourhood. The students were divided into eight groups, resulting in the delivery of 8 neighbourhood analyses and design proposals geared at improving health by interventions in the public domain. The results were discussed in a public event.

Figure 2, Field work with student-participants at the site of the future Maastricht ICC during the design workshop. Photo: Clara Kommenda

3. Results and analysis

3.1 Results step 1: joint problem diagnosis

Two focus group interviews with stakeholders in both spatial projects were conducted to reconstruct the spatial planning projects and identify barriers regarding the integration of health. These barriers are described below for both cases jointly.

Policy makers, designers and education boards consider schools and childcare centers as one of the few remaining places in neighborhoods where spontaneous interaction between different social groups takes place. Accordingly, promoting and enabling social interaction was put on the foreground in both spatial planning projects as a contribution to a healthy built development. Since school buildings and school yards are considered semi-public spaces, many stakeholder groups were involved in the development process. This required intensive collaboration, because of the different claims put on the scarce space in urbanized areas. Examples of stakeholder groups include the parties that initiated the plans (i.e. municipalities and school boards) and users of the ICC and the nearby space (e.g. schools, childcare), but also local residents and stakeholders from other facilities in the neighborhood such as community centers and sports clubs.

At the start of both spatial projects, residents, municipalities and education board members were enthusiastic about including health in the designs for the area surrounding the ICCs. However, the two main health ambitions in both projects, promoting social interaction and active transportation, got out of sight and were insufficiently integrated in the provisional plans for the ICCs. Integrating health appeared to be a difficult process, especially when it comes to health promotion (i.e. an environment that encourages healthy behaviors) as opposed to health protection (i.e. an environment in which the pressure on health is as low as possible). The barriers for integrating health can be divided into two underlying main challenges:

1) Health as a broad concept

At the start, stakeholders were enthusiastic about taking health into account in the development of the ICC buildings and its vicinity. However, health is a broad concept and themes such as physical activity or social interaction can be interpreted in different ways by stakeholders. Therefore, at the start of the projects it was not clear whether there was sufficient support for the plans among residents for instance. This was particularly evident in relation to promoting social interaction. Promoting social interaction between different groups in the public space was found to be difficult. As the neighborhood park next to the ICC in Maastricht would also be used by the schoolchildren, residents started to worry about its accessibility, the facilities in the existing park (such as the dog walking area), and the amount of space remaining available for residents. The ambitions for social interaction also appeared to conflict with social safety in both cases. Public accessibility of areas around the schools was not desired by the education boards and parents, because of the importance assigned to the social safety of the schoolchildren.

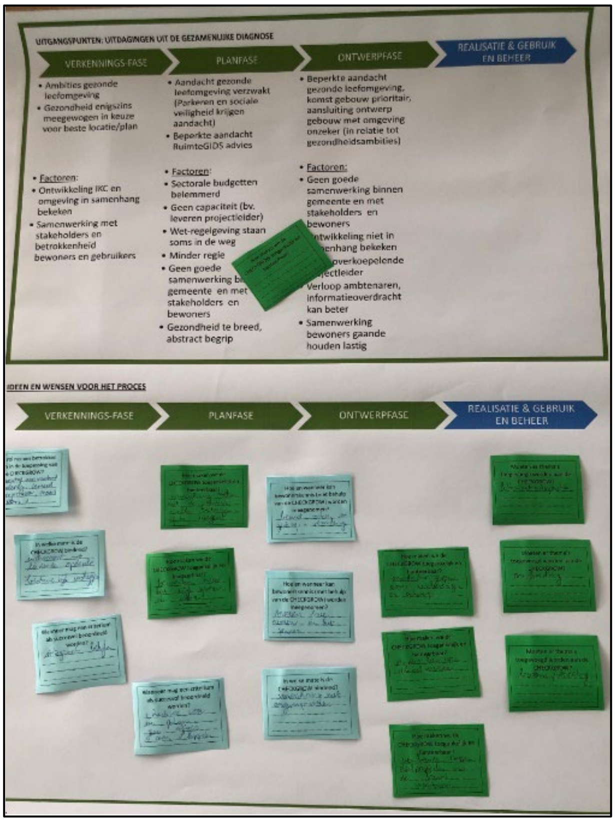
2) Intersectoral collaboration

The health sector was not always represented in the spatial planning processes. Creating and maintaining a healthy built environment requires cooperation between different stakeholders, but also between departments within the municipality (e.g. education, health, sports, mobility). Specific barriers related to intersectoral collaboration that were identified include laws and regulations, lack of mandate, sectoral budgets, and different interests and opinions among representatives from different sectors. Coordinating project leaders to break down these barriers and directing the spatial development process were lacking in both cases.

3.2 Results step 2: co-designing improvements

The results of the co-design sessions are presented below, separately for both cases. Based on these sessions, the scientific researchers involved in RuimteGIDS Living Lab derived two main proposals for improvement of the Check&Grow, which are outlined in section 3.2.3.

Figure 3: Poster used during the co-design session in Maastricht. The post-its contain ideas for improvements regarding the process (i.e., the application of the Check&Grow tool and the collaboration process).



3.2.1 Results co-design session Maastricht

With regard to the application of the Check&Grow tool, it became clear that it could be used at the start of a spatial planning project to have a well-founded point of departure, for instance about the need to involve particular expertise and financing. Participants indicated that the tool could be used by a designer commissioned by the project leader. The tool could be used to assess the health aspects of a spatial development and its context, to communicate to decision makers and residents, and to support decisions. After discussing the themes originally included in the Check&Grow tool, participants expressed the need to include climate adaptation, including heat stress. Attention for soil pollution and mental health was also requested.

3.2.2 Results co-design session Kerkrade

With regard to the application of the Check&Grow tool, participants expressed a need for some kind of weighing of interests. Examples that were discussed include the use of criteria such as “schools should not be developed in the immediate vicinity of main roads” and using a scoring system (e.g. 1 indicates not considered and 5 indicates perfectly considered). Participants found that the tool should be applied as early as possible in spatial planning projects so that interests and related projects can be listed and relevant policy fields can be involved. There was also a call to add climate adaptation to the Check&Grow tool, including variation of trees, adding shade and greenery, orientation, material and color of buildings, and vegetation. Finally, there was a request for a fill-in template so that the output of the tool is to the point and identical after each application.

3.2.3 Two main proposals for the improvement of the Check&Grow tool

The Check&Grow tool is intended to make health a more robust value in spatial planning. Considering the two co-design sessions, RuimteGIDS team members identified two main lines for improvement. First, health can be made a more robust value in the collaborations through new roles, tasks and procedures (see box 1). Second, the health values could be made more robust by connecting it to other challenges such as climate adaptation and mobility (see box 2). Both of these challenges are high on the policy agenda and already better safeguarded in spatial planning. Another, related way to promote the integration of health in spatial planning, would be the adoption of standards or ‘rules of thumb’. An example could be the 3-30-300 rule of thumb for urban green space (Konijnendijk 2021, 2023).

Box 1 elements of proposal 1

Proposal 1

- Appoint an on-going coordinating project manager in every spatial development project.
- Take sufficient time in the exploration phase of a project to reach consensus on how to operationalize health in the spatial development project.
- Appoint an independent facilitator for the consensus process.
- Lay down the decisions on how to operationalize health in a memorandum at the start of a project

Box 2 elements of proposal 2

Proposal 2

- Connect health to more robust values
  For example, to (policy actions on) climate adaptation
- Adopt standards and rules of thumb for healthy spatial development
  For example, the 3-30-300 rule of thumb for urban greenspace

Results step 3: testing by policymakers and urban designers

3.3.1 Results policy test Maastricht and Kerkrade

Both in Maastricht and Kerkrade, participants discussed the proposed improvements. According to the participants, the project manager should be a person knowledgeable about local policy and planning procedures. The independent facilitator was expected to work well in case of conflicting interests or when emotions play a major role. Regarding the memorandum, the participants indicated that health values should be included as specific as possible (e.g., “promoting physical activity” is not specific enough, while “promoting active transportation” is). Another recommendation regarding this memorandum was to leave room for amendments. Considering feasibility, participants warned for a lack of capacity in municipalities to appoint ongoing coordinating project managers for each spatial planning project.

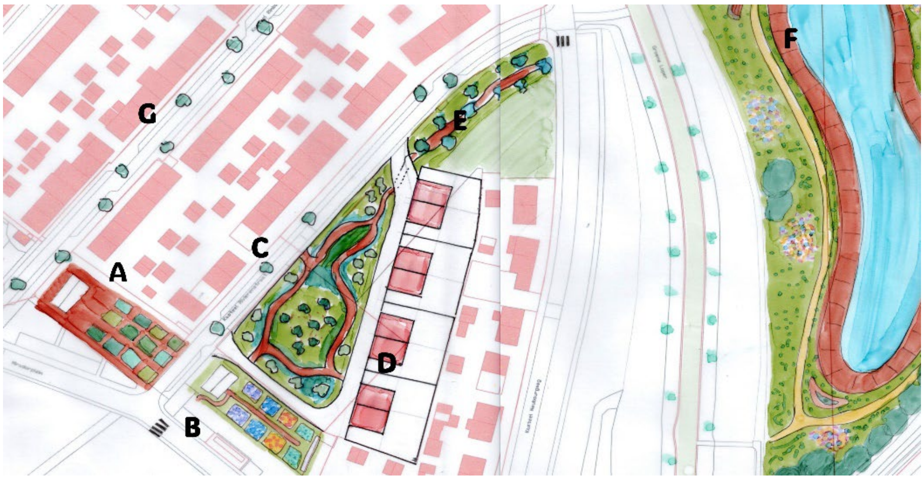
The second proposed improvement led to some discussion. With respect to the proposal to adopt standards or rules, the importance of keeping a local identity in the built environment and leaving room for the designer to achieve this were stressed. In addition, there were some doubts whether a single rule, such as the 3-30-300 rule, would cover all aspects of a healthy built environment (e.g., including active transportation, social interaction). The dominant opinion was that it would be very helpful to introduce more specificity regarding the integration of health in spatial planning processes, but without coercion. To illustrate, participants had a preference for guidelines and rules of thumb for a healthy built environment, compared to strict, binding standards.

3.3.2 Results design test

In line with the expertise of the students, most attention was given to introducing more vegetation and different functions of public space – improving the resilience in face of climate change and favouring an active lifestyle and active transportation - over pavement and parking places. Participants faced the challenge of transforming existing neighbourhoods which are densely built and leave little space for transformation. They drew attention to the need for analysis and design on different scale levels. This was illustrated by the common finding that it is very difficult within densely built urban areas to increase the tree canopy cover to 30% or to provide each dwelling with sight of three trees (as prescribed in the 3-30-300 rule). The designers alternatively proposed a stronger focus on functionality, seeking to implement more inclusive and diverse programs in public spaces, and adopt planting schemes fitting that functionality.

The design experiment uncovered several ways in which the Check&Grow tool might be applied in a spatial design or planning process. Some groups chose to use it merely as a checklist. In this case, it was unclear how the tool influenced the design process. Other groups used the tool as a guide for discussion and strategic decisions. They started from precise observations in the analytical stage and decided on strategic choices to improve health aspects. Finally, some groups took the concepts and arguments from the Check&Grow checklist and reworked these into a new document, applying their own ideas about textual and graphic representation. They proved that the concepts can be integrated deeply in design processes and can influence the professional products of designers.

Figure 4: design proposal showing the challenge of inserting green in densely built streets in comparison to the opportunity to reprogram vacant areas with new open space functions (A, B, C) and additional dwellings (D). Design by Stan Baren, Len Boonen, Tim Moers, Milan van



Overbeeke, Stefanie van de Venne.

4. Discussion

4.1 Main findings

This project aimed to improve the Check&Grow tool in order to have a practical tool for policy makers and practitioners, thereby strengthening the integration of health in urban spatial planning projects. Through co-creation, two main improvements for the tool were proposed. The first improvement included recommendations regarding the collaboration process and the application of the tool. These recommendations are included in a user manual for the tool. The second improvement includes the proposal to connect health with other, more robust values in spatial planning such as climate adaptation and to adopt standards or rules of thumb for healthy spatial development.

4.2 Lessons learnt and implications

4.2.1 Standards and rules for a healthy built environment

There are hardly any procedures or standards to safeguard health promotion in spatial planning projects. One of the improvements of the Check&Grow tool is on standards and rules of thumb, in particular for the health promoting built environment. The 3-30-300 rule is becoming more and more popular and applied by many municipalities in the Netherlands, including Maastricht and Kerkrade. We could learn from quality standards in the field of health protection (Mierau en Toebes, 2021). A first step would be to list other available standards and rules regarding the health promoting environment (i.e. on the themes from table 1 such as physical activity or social interaction and inclusion). Subsequently, it would be useful to study the application and effects of such standards. For instance, it could be hypothesized that standards lead in practice to ambitions that are set at the minimum level. Another important question is whether sufficient room is left for citizen's knowledge and the designer's creativity and expertise when working with binding standards.

4.2.2 Adaptable approach

In contrast to many available tools for a healthy built environment (for an overview we consulted Dortmans, Melis, and Van Loon-Van der Logt, 2023), the Check&Grow was developed and improved in practice, supported by scientific research. In the TAR approach that RuimteGIDS has adopted, experimenting, learning and adapting are key elements. In this regard, we consider the context highly important. For instance, The Environment and Planning Act, which took effect as of 2024, shapes a new legislative frameworks for collaboration processes and procedures. We propose to continuously consider local translations of the instrument and search for the best intervention-context fit (Cohen et al., 2008; Chambers and Norton, 2016).

4.3. Strengths and limitations

A Living Lab is a promising approach for the study of complex health problems and interventions. Unfortunately, it was not feasible to test the improved Check&Grow in a real-world setting. However, the policy test gave insight into the effectiveness of the improved tool. Furthermore, in the design test, eight groups of creative students worked intensively together with the tool and reflected on its application and usability. Within the Living Lab, it could not be determined how health would eventually be integrated in the final design of the ICC buildings and surroundings. In both spatial projects, we mainly looked at the exploration and planning phases, as later phases were not initiated at that time. Additionally, previous research shows that public space remains in a state of flux once plans are realized (Horstman & Knibbe, 2022), indicating that merely planning and realizing single health promoting projects in the environment are not sufficient. Finally, some processes proved less easy to reveal, such as informal processes including verbal agreements between planning group members. Interviews with municipal policy staff showed that some health aspects would be included into the design of the public space through more informal pathways. There are no indications that socio-economic differences between the two Living Lab locations had an influence on the outcomes of this research, preliminary indicating the usefulness of the tool for both more affluent and vulnerable areas.

Conclusion

Within intermediate-scale urban spatial planning projects, health is a vulnerable value. In particular, health promotion through interventions in the environment was not fully implemented in both planning projects within the current Living Lab. Through co-creation, we came up with two main improvements to address the barriers for integrating health. These improvements were included into the Check&Grow tool and its user manual. We propose to investigate a more binding way of safeguarding health. This involves linking health to more robust values (such as climate adaptation) and using rules of thumb and standards.

Acknowledgements

Funded by The Dutch Organisation for Health Research and Development (ZonMw): 10820012210006. This conference paper is based on the Dutch version of the project report entitled “Een gezonde leefomgeving met de Check&Grow: geleerde lessen over de integratie van gezondheid in ruimtelijke projecten en de doorontwikkeling van het instrument Check&Grow” [a healthy built environment with the Check&Grow: lessons learnt about the integration of health in spatial planning projects and the improvement of the Check&Grow tool]. We are grateful for the participation of the local stakeholders in this project.

References

Bikomeye, J. C., Balza, J., & Beyer, K. M. (2021). The impact of schoolyard greening on children’s physical

activity and socioemotional health: A systematic review of experimental studies. International journal of environmental research and public health, 18(2), 535.

Cohen, D. J., Crabtree, B. F., Etz, R. S., Balasubramanian, B. A., Donahue, K. E., Leviton, L. C., ... & Green, L. W. (2008). Fidelity versus flexibility: translating evidence-based research into practice. American journal of preventive medicine, 35(5), S381-S389.

Chambers, D. A., & Norton, W. E. (2016). The adaptome: advancing the science of intervention adaptation.

American journal of preventive medicine, 51(4), S124-S131.Gevers, D.W.M. , Oosterbroek, B., Akkermans,

S., Aardening, C., Esser, P., Knibbe, M., ... & Kremers, S. (2023). Ruimte Maken voor Gezondheid In De Stad: Lessen uit de Zuid-Limburgse steden Maastricht en Kerkrade.

Dortmans, K., Melis, K., & Van Loon-Van der Logt, M. (2023). Instrumenten Gezonde Leefomgeving in Nederland. *TSG-Tijdschrift voor gezondheidswetenschappen*, *101*(4), 157-166.

Gevers, D.W.M. Vonken, L., van de Weijer, M., Oosterbroek, B., Akkermans S., & Esser P. (2021).

Kernkindcentrum de Groene Loper “Een gezonde ontwikkeling van het Leeuwenpark.

https://www.ruimtegids.eu/media/attachments/2021/08/24/ruimtegids_kkc_gl_gezonde-ontwikkeling-van-het-leeuwenpark.pdf

Konijnendijk, C. (2021). The 3-30-300 rule for urban forestry and greener cities. *Biophilic Cities Journal*, *4*(2), 2.

Konijnendijk, C. (2023). Evidence-based guidelines for greener, healthier, more resilient neighbourhoods:

Introducing the 3–30–300 rule. *Journal of forestry research*, *34*(3), 821-830.

Mierau, J. O., & Toebes, B. C. (2023). Towards legally mandated public health benchmarks. International

Journal of Health Policy and Management, 12.

Ministry of Health (2018). Nationaal Preventieakkoord [National Prevention Agreement].

Ministry of Infrastructure and Environment (2016). Omgevingswet [Environment and Planning Act]. The Statute Book: The Hague

Horstman, K., & Knibbe, M. (2022). Gezonde stad: uitsluiting en ontmoeting in de publieke ruimte. De Graaff, Uitgeverij.

RuimteGIDS. (2019). Ruimte maken voor gezondheid in de stad: een Zuid-Limburgse kennisagenda.

https://www.ruimtegids.eu/images/19112019_RuimteMakenVoorGezondheidInDeStad_KennisagendaZuidLimburg_def.pdf

Scholl, C., & de Kraker, J. (2021). The practice of urban experimentation in Dutch city labs. *Urban Planning*, 6(1), 161-170.

Sykes, B., & Musterd, S. (2011). Examining neighbourhood and school effects simultaneously: What does the

Dutch evidence show?. Urban studies, 48(7), 1307-1331.

The Council for the Environment and Infrastructure (2018). De stad als gezonde habitat. Gezondheidswinst door Omgevingsbeleid. [The city as a healthy habitat. Health gains by environmental policy].

https://www.rli.nl/sites/default/files/de_stad_als_gezonde_habitat_def.pdf

3 Healthy cities & nature-based living (with care) concepts: **Conference paper**

Evaluating Perceived Restorativeness of Natural Landscapes through Virtual Reality: The Effects on Mental Health of Students in Design Disciplines in China

Shuang Liang[1], Pai Liu[1,2*], Qingjun Zou[1], Jessica Fernandez[3], Masi Mohammadi[2]

[1] School of Architecture and Fine Arts, Dalian University of Technology, China

[2] Chair or Smart Architecture Technology, Eindhoven University of Technology, The Netherlands

[3] College of Environment + Design, University of Georgia, Georgia

*Corresponding author: Pai Liu (pail@dlut.edu.cn)

Abstract: Previous research suggests that natural landscapes have a positive impact on the mental health of college students. In China, college students aged 18 to 24 are the largest group reporting depression, accounting for 35% of the affected population, especially after prolonged COVID-19 lockdowns on campuses. In particular, students in design disciplines have a high demand for the therapeutic value of natural landscapes.

This study measures the therapeutic effects of different natural landscapes on students from various design disciplines using virtual reality (VR) technology and the Perceived Restorativeness Scale (PRS) based on Attention Restoration Theory (ART). The results indicate that different landscapes have varying therapeutic effects on students from different design disciplines, while forest scenes are universally favored by students across all design disciplines. The insights gained from this study will contribute to the psychological well-being treatment of university students in design disciplines. In the future, more detailed research could be conducted to compare the effects of different landscape elements on students and expand into more disciplinary fields.

Keywords: Design Disciplines, Perceived Restorativeness, Attention Restoration Theory, Nature Therapy

1. Introduction

Natural landscapes have been acknowledged for their positive effects on college students' mental well-being. Exposure to natural environments like parks and ocean scenes has been shown to alleviate symptoms of depression and anxiety (Finlay et al., 2015; Garrett et al., 2019; Pouso et al., 2021). In China, college students from 18 to 24 years old are the largest group of people who reported depression accounting for 35% of the affected group (Chai & Shek, 2024; Z. Liu et al., 2021), which was particularly true after extended COVID-19 lockdowns on college campuses (J. Liu et al., 2024). For students in design disciplines, due to the nature of the design field, they may possess a deeper understanding and sensitivity towards aesthetics and visual perception. Additionally, they tend to prioritize the impact of natural landscapes on people's psychological and physical well-being. Therefore, they have higher expectations for landscape designs that offer therapeutic value. In addition to the pandemic-induced isolation and limited access to nature on urban campuses, the special preferences of design students indicate a need to investigate effective natural landscapes to support students' mental well-being on restricted campuses (Matsuoka, 2010; Sevenant & Antrop, 2010; Yeh & Li, 2014).

Different from students of non-design disciplines, students who study design-related majors usually have different tastes in natural and built environments. They may evaluate the landscapes from a more professional perspective and may be concerned about the points that others and the public do not notice. For example, landscape students may judge the planting design of a botanical garden rather than enjoy the beauty of flowers. Their threshold to get environmental stimuli are assumed to be higher than general, indicating a difficulty in the perceived restorative values to natural landscapes (Gulwadi et al., 2019; Hung & Chang, 2022; Kuper, 2017).

Starting in the 1960s, researchers of environmental psychology developed multiple frameworks to interpret the efficacy of natural landscapes on mental health. The Attention Restoration Theory (ART) developed by Kaplan is a representative framework for understanding environmental restorativeness, emphasizing factors including "Being-away", "Coherence (Extent)", "Fascination", and "Compatibility". "Being away" refers to the degree to which participants feel removed from their everyday environment; "Coherence" to the degree of intrinsic consistency or correlation among elements in the environment; "Fascination" to the degree of attractiveness of the environment to participants; and, "Compatibility" to the degree of match between the environment and individual needs or expectations (Grace et al., 2024; Q. Liu et al., 2020; Pearson et al., 2024). These factors shape individual perceptions of the restorativeness of natural environments and contribute to improved emotional well-being and mental revitalization(Kaplan & Kaplan, 2009; Kaplan & Peterson, 1993). This study employs the Perceived Restorativeness Scale (PRS), a scale developed from ART that measures the perceived restorative values after experiencing environmental stimuli. In this study, the stimuli include scenes of natural landscapes.

In recent years, virtual reality (VR) technology has emerged as a tool to explore the restorative qualities of natural landscapes, especially in the post-COVID-19 era. Virtual environments can be personalized to cater to individual preferences, offering a range of scenes from forests to beaches. This innovative application of technology holds promise in providing accessible and convenient restorative experiences, especially in situations where physical access to natural surroundings is limited, such as during lockdown conditions (Annerstedt et al., 2013; Spangenberger et al., 2024; Yu et al., 2020). Since college students have shown acceptance of VR as an effective tool for learning and relaxation, it is a viable option for enhancing mental well-being when physical access to nature is restricted (Chan et al., 2024).

This research explores the restorative effects of various natural landscapes on college students from different design majors through virtual reality (VR) technology. The insights gained from this study contribute to knowledge on mental health therapy options for college students, especially in design disciplines.

2. Methods

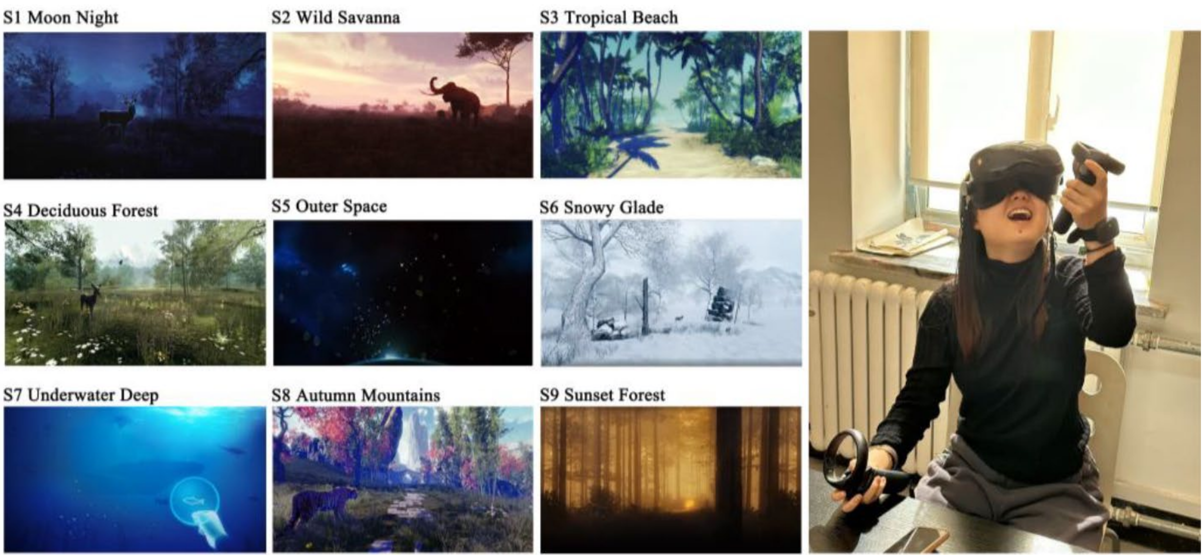


Figure 1. Experiment procedure and Explanation of Scenarios

2.1 VR experiment

This study collected physiological data, including heart rate and brainwaves, during the VR experiment. Afterwards, researchers conducted a brief interview using the Perceived Restorativeness Scale for investigation. The participants were students from various design disciplines, and the process was based on the following 5 steps:

1. Researchers placed a brainwave sensor and heart rate sensor on participants. Participants closed their eyes and relaxed for ten minutes, while researchers recorded one minute of physiological data during this period.
2. The researchers equipped the participants with VR headsets and explained the operating procedures. The participants selected and experienced three scenes from the nine scenes displayed on the homepage.

3. Participants entered each of the three chosen scenes and experienced them for three minutes each. Researchers recorded physiological data for one minute in each of the three scenes.
4. The participants took off the VR headsets and rested with their eyes closed for ten minutes. During this period, the researchers recorded one minute of physiological data.
5. Researchers removed the equipment from participants and conducted brief semi-structured interviews. Finally, participants scanned a QR code to submit a survey questionnaire, concluding the entire process.

For the purpose of this study, one minute of physiological data collection time is assumed sufficient. This timeframe is adequate for capturing participants' physiological responses to specific stimuli, thus enabling the acquisition of high-quality and reliable data (Peng et al., 2023).

2.2 Measurement

Survey-Perceived Restorativeness Scale. The survey included two parts consisting of demographic questions and the Perceived Restorativeness Scale (PRS). The demographic questions collected the basic information of the participants and their previous VR experiences. The PRS collected the perceptions of restorative qualities of the selected environments displayed in virtual reality. The PRS is developed from Kaplan's attention restoration theory (Subiza-Pérez et al., 2020; Van den Berg et al., 2014; Young et al., 2020), measuring the quality of environmental restoration using four subscales: "Being Away", "Fascination", "Coherence (Extent)" and "Compatibility".

Data Analysis. Descriptive statistics were used to analyze the demographic data collected in the survey. The PRS data combined with an eSense index and heart rates was analyzed using a ANOVA and mixed factorial analysis to identify the significance of factors influencing the perception of different nature through virtual reality (Latini et al., 2024). One-way ANOVA were first applied to detect the variances of PRS and physiological variables depending on the scenes.

3. Results and analysis

3.1 Demographic Analysis

The study included 50 students from 6 different design disciplines (Table 1). Among the participants, 64% were female and 36% were male. Regarding the age distribution, 62% of participants are aged between 18 and 23, while 38% were aged between 24 and 29. Educational backgrounds varied, including undergraduate, master's, and doctoral students, with master's students representing 82% of the sample. Nearly half of the participants had no prior experience with virtual reality before the study. Only 2 students were not willing to experience VR again, while the remaining students indicated a willingness to participate again.

Tabel 1. Demographic information of participants

		Count	Frequency
Gender	Male	18	36.00%
	Female	32	64.00%
Age	18-23	31	62.00%
	24-29	19	38.00%
Education level	Undergraduate Students	7	14.00%
	Master Students	41	82.00%
	Doctoral Students	2	4.00%
Major	Architecture	8	16.00%
	Environment design	25	50.00%
	Fine arts	2	4.00%
	Industrial design	5	10.00%
	Urban and rural planning	5	10.00%
	Visual communication design	5	10.00%
VR experience	Having VR experience	28	56.00%
	No VR experience	22	44.00%
Willingness to participate in VR activities again	Willing to participate	48	96.00%
	Refuse to participate	2	4.00%

Means of Perceived Restorativeness

Tabel 2. Means of PRS

		Being Away		Fascination	
	Qty	Mean	Std	Mean	Std
s1/Moon Night	17	5.337	0.940	5.066	1.176
s2/Wild Savanna	13	5.944	1.237	5.602	1.089
s3/Tropical Beach	15	5.350	1.012	5.478	0.821
s4/Deciduous Forest	19	5.869	0.873	5.640	1.012
s5/Outer Space	22	5.815	0.896	5.343	1.099
s6/Snowy Glade	11	5.571	1.235	5.182	1.139
s7/Underwater Deep	15	5.797	1.032	5.535	1.048
s8/Autumn Mountains	13	5.630	1.120	5.409	0.999
s9/Sunset Forest	25	5.486	1.186	4.840	1.438

		Coherence		Compatibility		Perceived Restorativeness	
	Qty	Mean	Std	Mean	Std	Mean	Std
s1/Moon Night	17	5.468	0.715	4.426	1.494	5.012	0.940
s2/Wild Savanna	13	4.861	1.094	5.141	1.262	5.494	1.006
s3/Tropical Beach	15	5.466	1.105	5.216	0.926	5.374	0.755
s4/Deciduous Forest	19	5.425	1.188	5.289	1.090	5.576	0.811
s5/Outer Space	22	5.096	1.193	4.970	1.377	5.336	0.975
s6/Snowy Glade	11	5.732	1.136	4.959	1.299	5.285	1.034
s7/Underwater Deep	15	5.400	1.247	5.215	1.453	5.517	1.069
s8/Autumn Mountains	13	5.076	1.142	5.371	1.253	5.413	0.964
s9/Sunset Forest	25	5.224	1.352	4.721	1.426	4.964	1.156

Among the nine VR scenes, S4 Deciduous Forest showing landscapes of greenery had the highest Fascination score, and S9 Sunset Forest had the lowest Fascination score though it was the scene most selected. The sparse tree landscape and rich wildlife in the S2 Wild Savanna scene contributed to its strong sense of being away and the lowest Coherence value. S6 Snowy Glade, selected the least frequently, features snow-covered mountains and meadows, presenting consistent landscape elements and the highest Coherence value. S1 Moon Night features an unknown and mysterious night sky, and possessed the lowest compatibility value. In contrast, S8 Autumn Mountains was a more familiar environment for participants, thus having a higher compatibility value. Overall, there is a close correlation between perceived restorativeness and scene attractiveness.

3.2 ANOVA Analysis of PRS and Physiological Responses

Tabel 3. Homogeneous analysis of PRS and Physiological Responses

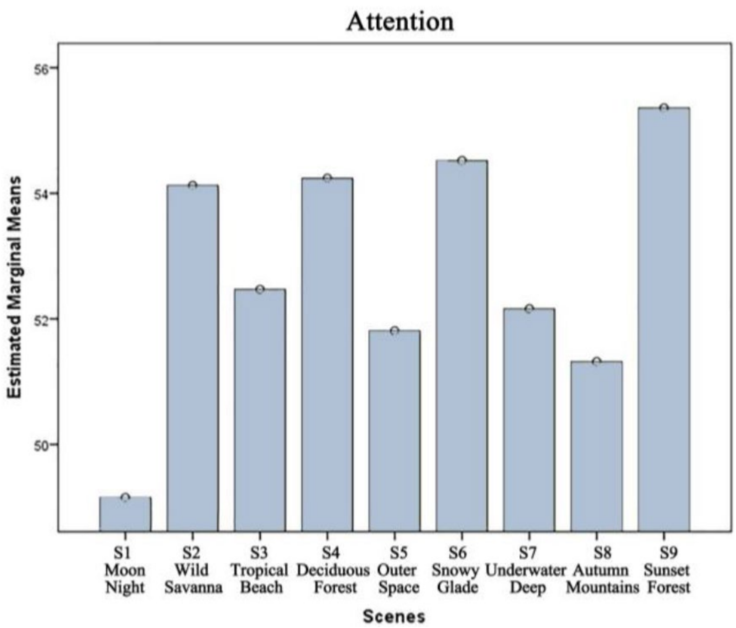
Attention					Heart Rate				
Scenes	1	2	3	4	Scenes	1	2	3	4
s1/Moon Night	49.15				S8/Autumn Mountains	68.02			
s8/Autumn Mountains	51.32	51.32			S3/Tropical Beach	68.30			
S5/Outer Space	51.81	51.81	51.81		S1/Moon Night	69.03			
S7/Underwater Deep		52.16	52.16		S7/Underwater Deep		71.69		
S3/Tropical Beach		52.47	52.47	52.47	S2/Wild Savanna		71.85		
S2/Wild Savanna		54.12	54.12	54.12	S9/Sunset Forest		72.69		
S4/Deciduous Forest		54.24	54.24	54.24	S4/Deciduous Forest		72.90	72.90	
S6/Snowy Glade			54.52	54.52	S5/Outer Space			74.32	74.32
S9/Sunset Forest				55.36	S6/Snowy Glade				74.98

Meditation			Perceived Restorativeness					
Scenes	1	2	Scenes	1	2	3	4	5
S1/Moon Night	48.56		S9/Sunset Forest	4.9642				
S5/Outer Space	48.89		S1/Moon Night	5.0121				
S8/Autumn Mountains	49.60		S6/Snowy Glade		5.2848			
S2/Wild Savanna	51.02	51.02	S5/Outer Space		5.3359			
S9/Sunset Forest	51.21	51.21	S3/Tropical Beach		5.3737	5.3737		
S4/Deciduous Forest	51.24	51.24	S8/Autumn Mountains		5.4130	5.4130	5.4130	
S3/Tropical Beach	51.47	51.47	S2/Wild Savanna			5.4936	5.4936	5.4936
S7/Underwater Deep		53.43	S7/Underwater Deep				5.5167	5.5167
S6/Snowy Glade		53.60	S4/Deciduous Forest					5.5760

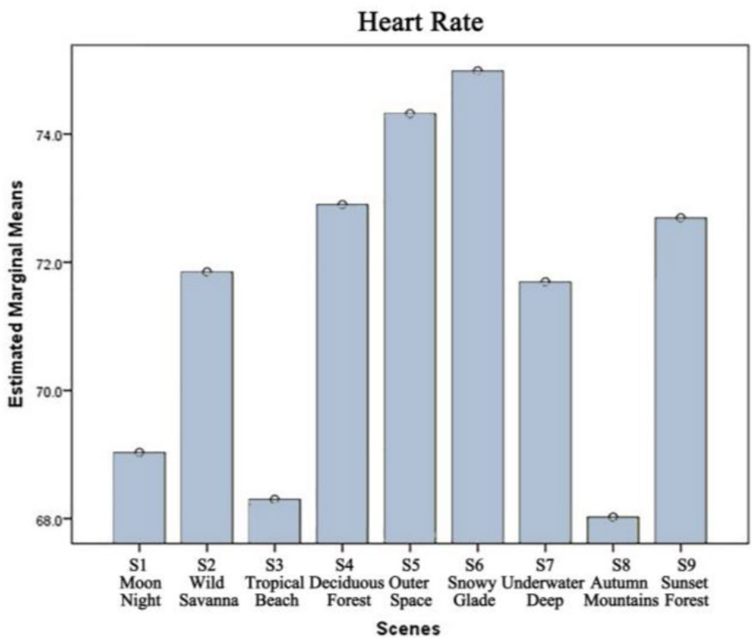
The analysis of variance (ANOVA) for PRS and physiological responses indicates that the homogeneity of variance test for meditation did not show any statistical significance ($p > 0.05$), while other charts exhibited statistical significance ($p < 0.05$). The variance analysis of the attention chart is divided into four groups, each containing a relatively large number of scenes, with subtle differences.

The heart rate data shows significant differences. Combined with the analysis of the Perceived Restorativeness Scale (PRS) and the subjects' subjective feelings, scenes such as S3 Tropical Beach, which have a low sense of being away, have the lowest HR values; scenes with low coherence like S2 Wild Savanna have moderate HR levels; whereas scenes with lower compatibility like S6 Snowy Glade induce tension in participants, resulting in the highest HR values.

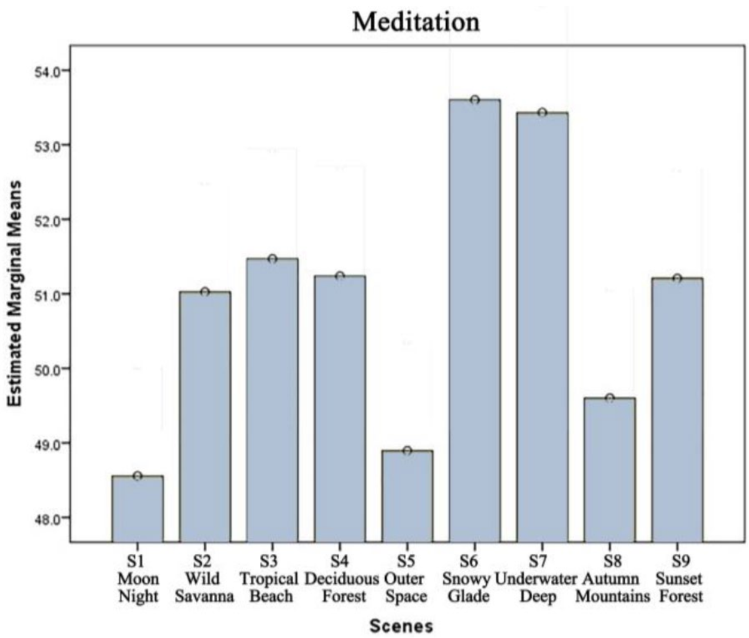
The perceived restorativeness was lowest in scenes S1 Moon Night and S9 Sunset Forest; it was highest in scenes S4 Deciduous Forest and S7 Underwater Deep; and, the rest of the scenes were relatively average.



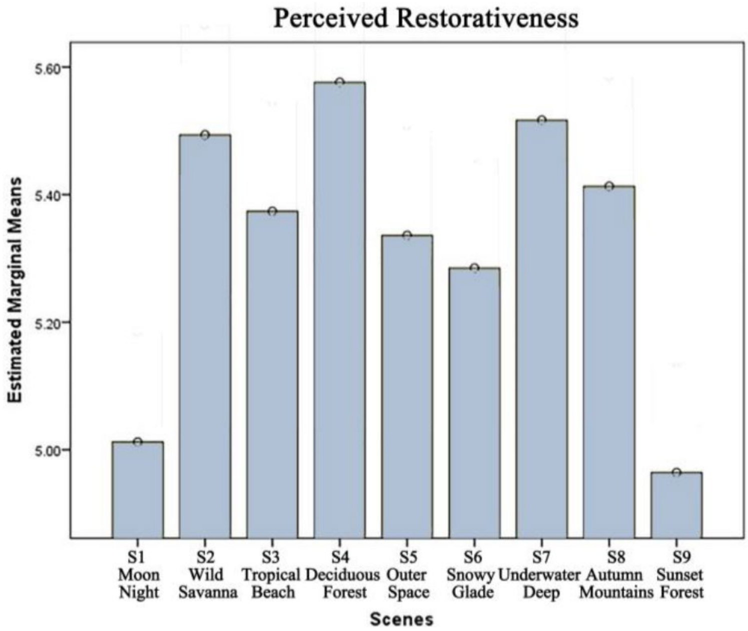
a. Estimated Means of Attention by Scenarios



b. Estimated Means of Heart Rate by Scenarios



c. Estimated Means of Meditation by Scenarios



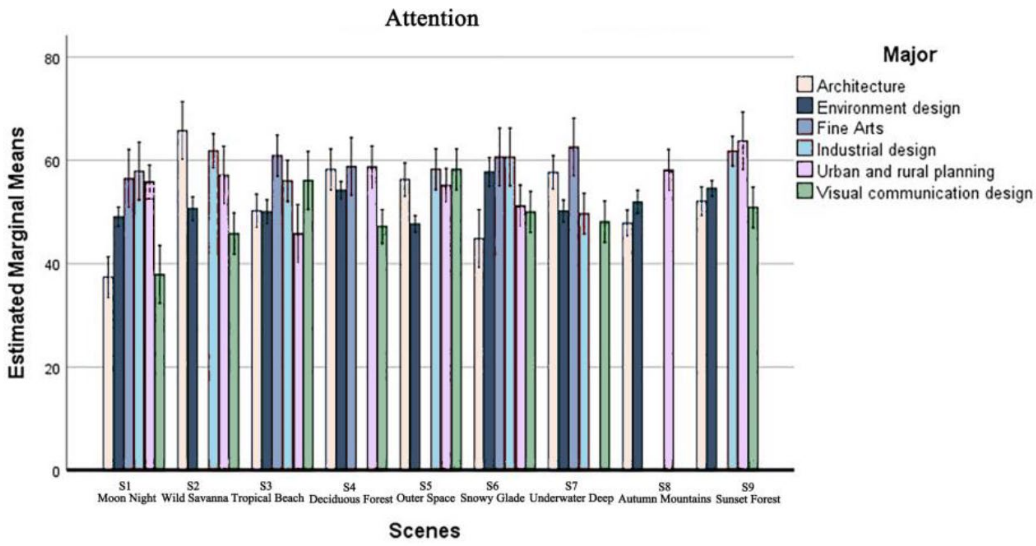
d. Estimated Means of Perceived Restorativeness by Scenarios

Figure 2. The means of PRS and Physiological Responses analyzed by scenarios

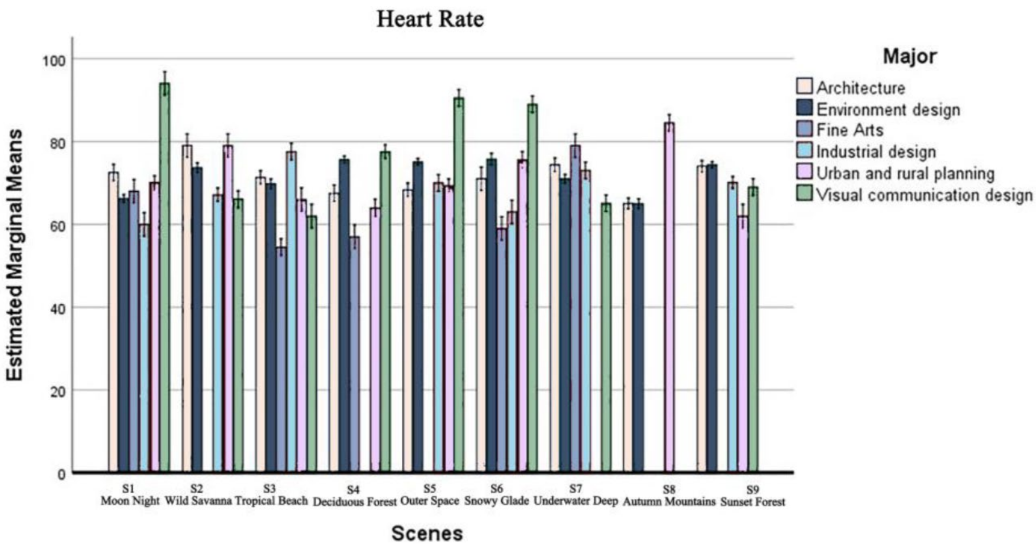
As the most commonly encountered green space, S4 Deciduous Forest exhibits the highest Fascination value. Participants' subjective perceptions and physiological responses both reflect its beneficial healing effects.

Based on the Perceived Restorativeness Scale (PRS) and interviews, it is analyzed that the S6 Snowy Glade scene exhibits strong internal coherence, with the highest coherence value. Despite participants subjectively finding this scene somewhat dull, their physiological responses were very positive.

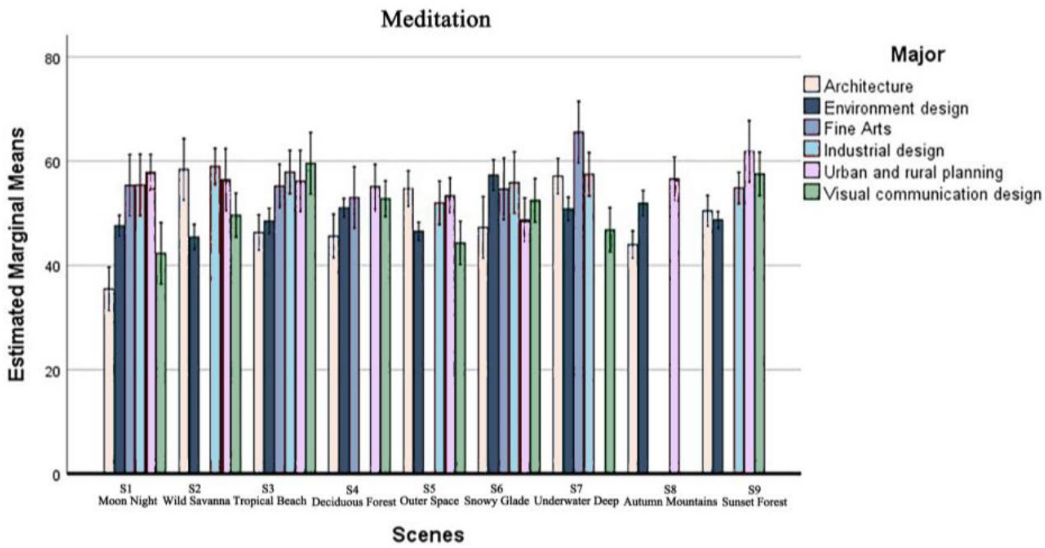
Scenes S1 Moon Night and S9 Sunset Forest, with the lowest Compatibility values, evoked feelings of tension and discomfort among participants, showing unfavorable physiological responses and subjective experiences.



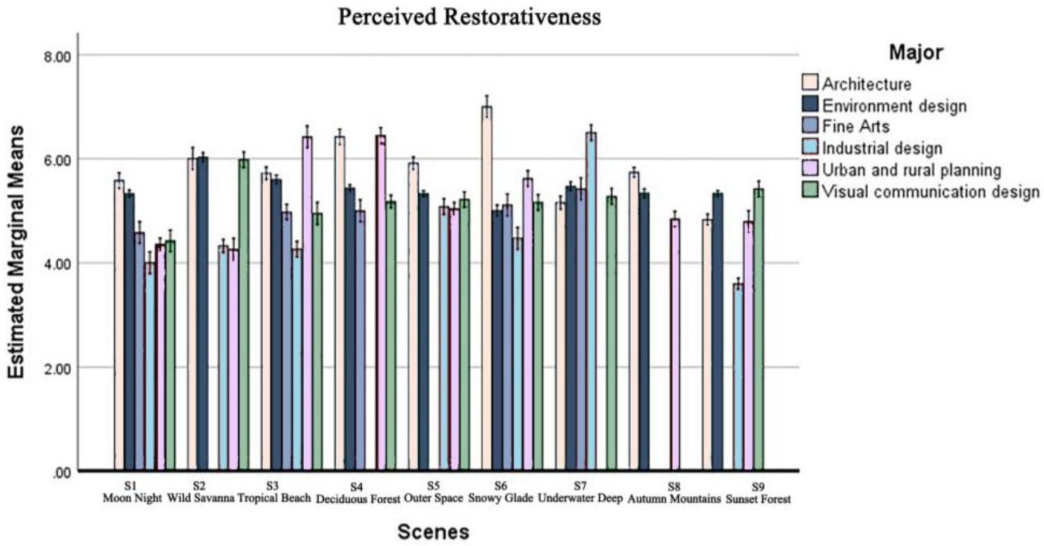
a. Attention Differences by Majors



b. Heart Rate Differences by Majors



c. Meditation Differences by Majors



d. Perceived Restorativeness Differences by Majors

Figure 3. The means of PRS and Physiological Responses analyzed by majors

Students majoring in Architecture and Urban and Rural Planning demonstrated good therapeutic effects in the low coherence scene S2 Wild Savanna. Although they perceived the high coherence scene S6 Snowy Glade with high restorativeness ratings, their physiological responses were average. Conversely, students in the Environment Design major rated the restorativeness of the high coherence scene S6 Snowy Glade the lowest, but exhibited the best physiological responses; they rated the restorativeness of the low coherence scene S2 Wild Savanna the highest, but experienced the poorest actual therapeutic effects.

Students majoring in Fine Arts did not select the low-coherence scene. In the S7 Underwater Deep scene, they exhibit the highest Attention and Heart Rate values, resulting in the best therapeutic effects. Students majoring in Industrial Design subjectively preferred the S7 Underwater Deep scene, but their physiological responses across scenes were relatively even, indicating good adaptability to their environment.

Compared to students from other disciplines, students majoring in Visual Communication Design exhibited higher levels of tension in the S1 Moon Night scene, showing the highest heart rate values; in the low sense of being away S3 Tropical Beach scene, their emotional state was the most relaxed, with the lowest heart rate values.

4. Discussion

Low-coherence scenes have a better therapeutic effect on students majoring in Architecture and Urban and Rural Planning, while high-coherence scenes are more effective for students majoring in Environment Design. Scenes with a strong sense of being away are more therapeutic for students majoring in Visual Communication Design.

Students majoring in Architecture and Urban and Rural Planning subjectively highly appreciated scenes with high coherence, where orderly and coherent environments had better therapeutic effects. However, from physiological data, scenes with lower subjective ratings but lower coherence showed higher perceived recovery levels. The various changes and stimuli presented in low-coherence scenes may arouse curiosity and the desire to explore for these students, thus achieving therapeutic effects.

Students majoring in Environment Design tended to favor creative and personalized designs. Therefore, they subjectively leaned towards more positive evaluations of low-coherence environments. However, from a physiological perspective, high-coherence environments provided a stable environmental experience, helping students reduce cognitive load and achieve relaxation.

Students majoring in Visual Communication Design subjectively perceived the S2 Wild Savanna scene as having a strong sense of being away, evoking a feeling of novelty. However, according to physiological data, in the low sense of being away S3 Tropical Beach scene, students in this major demonstrated more stable emotions, which contributed to relaxation and healing.

Influenced by their artistic background, students in Fine Arts and Industrial Design disciplines prefer scenes that are clear, orderly, and evoke emotional resonance. These scenes also demonstrate excellent therapeutic effects.

Fine Arts students did not select low-coherence scenes like S2 Wild Savanna; they preferred clear, orderly environments that offer imaginative space for artistic inspiration. In the S7 Underwater Deep scene, these students exhibited the highest Attention and Heart Rate values, likely resonating artistically with the underwater sculptures in the scene, resulting in significant therapeutic effects.

On the other hand, students majoring in Industrial Design considered the perceived restorativeness of the S7 Underwater Deep scene to be the highest, perhaps due to their preference for innovative settings, where the deep-sea creatures in the scene may have sparked their interest. Students in this major exhibited relatively consistent physiological responses across different scenes, demonstrating strong environmental adaptability.

The Deciduous Forest scene was unanimously favored by various design disciplines.

The S4 Deciduous Forest scene is the most common green space in psychological therapy. Compared to other natural landscapes in virtual reality, the S4 scene had the highest attractiveness rating and perceived restorativeness, with physiological data values at an average level. People can achieve better therapeutic effects in familiar green environments (Stepansky et al., 2022).

Limitations

1. We selected widely-used virtual reality devices for the experiment, but there may be certain technical differences among different devices, potentially introducing errors. Additionally, despite our efforts to ensure that the selected scenes are highly immersive and therapeutic, we cannot rule out the possibility that differences in quality among different scenes may have some degree of impact on the experimental results.
2. The uneven distribution of participants' majors resulted in insufficient sample sizes for certain disciplines. This may affect the comprehensiveness and accuracy of the research results concerning different professional groups
3. Before the VR experiment, despite our efforts to ensure the representativeness and health status of the sample through recruitment processes and exclusion criteria, we cannot rule out the potential influence of differences in individuals' mental health statuses on the results.

5. Conclusion

This study utilized the Perceived Restorativeness Scale (PRS) and physiological measurements to investigate the recuperative abilities of students from different design disciplines across nine different virtual reality natural landscapes. Low coherence scenes with various changes stimulated the curiosity of students majoring in Architecture and Urban and Rural Planning; high coherence scenes provided a stable environmental experience, reducing cognitive load for students in the Environment Design major; and, students majoring in Visual Communication Design tended to be more relaxed in familiar environments. Students in Fine Arts and Industrial Design preferred scenes that stimulated their creativity. Forests, recognized as the most widely accepted green space, were unanimously favored by students in all design disciplines.

The insights gained from this study contribute to the psychological treatment of design discipline university students, inspiring designers to incorporate plants, natural lighting, and simulated natural landscapes into classroom or study spaces, or to provide virtual reality technology for psychological therapy. Future research could explore the diverse effects of natural landscapes and conduct more detailed investigations to compare the therapeutic effects of specific landscape elements.

References

Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, Å. M., & Währborg, P. (2013). Inducing physiological stress recovery with sounds of nature in a virtual reality forest — Results from a pilot study. *Physiology & Behavior*, *118*, 240–250. https://doi.org/10.1016/J.PHYSBEH.2013.05.023

Chai, W., & Shek, D. T. L. (2024). Mental health profiles and the related socio-demographic predictors in Hong Kong university students under the COVID-19 pandemic: A latent class analysis. *Psychiatry Research*, *331*, 115666. https://doi.org/10.1016/J.PSYCHRES.2023.115666

Chan, I. Y. S., Dong, Z., & Chen, H. (2024). Impacts of connections to the outside on underground space occupants' psychophysiological health: A virtual reality-based experimental approach. *Tunnelling and Underground Space Technology*, *147*, 105675. https://doi.org/10.1016/J.TUST.2024.105675

Finlay, J., Franke, T., McKay, H., & Sims-Gould, J. (2015). Therapeutic landscapes and wellbeing in later life: Impacts of blue and green spaces for older adults. *Health & Place*, *34*, 97–106. https://doi.org/10.1016/J.HEALTHPLACE.2015.05.001

Garrett, J. K., White, M. P., Huang, J., Ng, S., Hui, Z., Leung, C., Tse, L. A., Fung, F., Elliott, L. R., Depledge, M. H., & Wong, M. C. S. (2019). Urban blue space and health and wellbeing in Hong Kong: Results from a survey of older adults. *Health & Place*, *55*, 100–110. https://doi.org/10.1016/J.HEALTHPLACE.2018.11.003

Grace, M., Dickie, J., Brown, C., Bartie, P., & Oliver, D. M. (2024). Using solicited research diaries to assess the restorative potential of exposure to inland blue space across time. *Landscape and Urban Planning*, *241*, 104904. https://doi.org/10.1016/J.LANDURBPLAN.2023.104904

Gulwadi, G. B., Mishchenko, E. D., Hallowell, G., Alves, S., & Kennedy, M. (2019). The restorative potential of a university campus: Objective greenness and student perceptions in Turkey and the United States. *Landscape and Urban Planning*, *187*, 36–46. https://doi.org/10.1016/J.LANDURBPLAN.2019.03.003

Hung, S. H., & Chang, C. Y. (2022). How do humans value urban nature? Developing the perceived biophilic design scale (PBDs) for preference and emotion. *Urban Forestry & Urban Greening*, *76*, 127730. https://doi.org/10.1016/J.UFUG.2022.127730

Kaplan, S., & Kaplan, R. (2009). Creating a larger role for environmental psychology: The Reasonable Person Model as an integrative framework. *Journal of Environmental Psychology*, *29*(3), 329–339. https://doi.org/10.1016/J.JENVP.2008.10.005

Kaplan, S., & Peterson, C. (1993). Health and environment: A psychological analysis. *Landscape and Urban Planning*, *26*(1–4), 17–23. https://doi.org/10.1016/0169-2046(93)90004-W

Kuper, R. (2017). Restorative potential, fascination, and extent for designed digital landscape models. *Urban Forestry & Urban Greening*, *28*, 118–130. https://doi.org/10.1016/J.UFUG.2017.10.002

Latini, A., Torresin, S., Oberman, T., Di Giuseppe, E., Aletta, F., Kang, J., & D'Orazio, M. (2024). Virtual reality application to explore indoor soundscape and physiological responses to audio-visual biophilic design interventions: An experimental study in an office environment. *Journal of Building Engineering*, 108947. https://doi.org/10.1016/J.JOBE.2024.108947

Liu, J., Tai, Z., & Hu, F. (2024). Prevalence and coping of depression and anxiety among college students during COVID-19 lockdowns in China. *Journal of Affective Disorders*, *348*, 305–313. https://doi.org/10.1016/J.JAD.2023.12.061

Liu, Q., Wu, Y., Xiao, Y., Fu, W., Zhuo, Z., van den Bosch, C. C. K., Huang, Q., & Lan, S. (2020). More meaningful, more restorative? Linking local landscape characteristics and place attachment to restorative perceptions of urban park visitors. *Landscape and Urban Planning*, *197*, 103763. https://doi.org/10.1016/J.LANDURBPLAN.2020.103763

Liu, Z., Liu, R., Zhang, Y., Zhang, R., Liang, L., Wang, Y., Wei, Y., Zhu, R., & Wang, F. (2021). Association between perceived stress and depression among medical students during the outbreak of COVID-19: The mediating role of insomnia. *Journal of Affective Disorders*, *292*, 89–94. https://doi.org/10.1016/J.JAD.2021.05.028

Matsuoka, R. H. (2010). Student performance and high school landscapes: Examining the links. *Landscape and Urban Planning*, *97*(4), 273–282. https://doi.org/10.1016/J.LANDURBPLAN.2010.06.011

Pearson, A. L., Lin, Z., & Shortridge, A. (2024). Beauty is in the eye of the beholder: Moderate ability to predict perceptions of beauty, restorativeness, and naturalness, in imagery among 10,727 participants. *Landscape and Urban Planning*, *243*, 104958. https://doi.org/10.1016/J.LANDURBPLAN.2023.104958

Peng, B., Zhang, Y., Wang, M., Chen, J., & Gao, D. (2023). T-A-MFFNet: Multi-feature fusion network for EEG analysis and driving fatigue detection based on time domain network and attention network. *Computational Biology and Chemistry*, *104*, 107863. https://doi.org/10.1016/J.COMPBIOLCHEM.2023.107863

Pouso, S., Borja, Á., Fleming, L. E., Gómez-Baggethun, E., White, M. P., & Uyarra, M. C. (2021). Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health. *Science of The Total Environment*, *756*, 143984. https://doi.org/10.1016/J.SCITOTENV.2020.143984

Sevenant, M., & Antrop, M. (2010). The use of latent classes to identify individual differences in the importance of landscape dimensions for aesthetic preference. *Land Use Policy*, *27*(3), 827–842. https://doi.org/10.1016/J.LANDUSEPOL.2009.11.002

Spangenberger, P., Freytag, S. C., & Geiger, S. M. (2024). Embodying nature in immersive virtual reality: Are multisensory stimuli vital to affect nature connectedness and pro-environmental behaviour? *Computers & Education*, *212*, 104964. https://doi.org/10.1016/J.COMPEDU.2023.104964

Stepansky, K., Delbert, T., & Bucey, J. C. (2022). Active student engagement within a university's therapeutic sensory garden green space: Pilot study of utilization and student perceived quality of life. *Urban Forestry & Urban Greening*, *67*, 127452. https://doi.org/10.1016/J.UFUG.2021.127452

Subiza-Pérez, M., Vozmediano, L., & San Juan, C. (2020). Green and blue settings as providers of mental health ecosystem services: Comparing urban beaches and parks and building a predictive model of psychological restoration. *Landscape and Urban Planning*, *204*, 103926. https://doi.org/10.1016/J.LANDURBPLAN.2020.103926

Van den Berg, A. E., Jorgensen, A., & Wilson, E. R. (2014). Evaluating restoration in urban green spaces: Does setting type make a difference? *Landscape and Urban Planning*, *127*, 173–181. https://doi.org/10.1016/J.LANDURBPLAN.2014.04.012

Yeh, Y. S., & Li, Y. M. (2014). Design-to-lure in the e-shopping environment: A landscape preference approach. *Information & Management*, *51*(8), 995–1004. https://doi.org/10.1016/J.IM.2014.06.005

Young, C., Hofmann, M., Frey, D., Moretti, M., & Bauer, N. (2020). Psychological restoration in urban gardens related to garden type, biodiversity and garden-related stress. *Landscape and Urban Planning*, *198*, 103777. https://doi.org/10.1016/J.LANDURBPLAN.2020.103777

Yu, C. P., Lee, H. Y., Lu, W. H., Huang, Y. C., & Browning, M. H. E. M. (2020). Restorative effects of virtual natural settings on middle-aged and elderly adults. *Urban Forestry & Urban Greening*, *56*, 126863. https://doi.org/10.1016/J.UFUG.2020.126863

3 Healthy cities & nature-based living (with care) concepts: **Conference paper**

Nature and Mental Health of Older Adults: A study investigating the efficacy of landscapes through virtual reality

Qingjun Zou[1], Pai Liu[1,2*], Shuang Liang[1], Jessica Fernandez[3], Masi Mohammadi[2]

[1] School of Architecture and Fine Arts, Dalian University of Technology, China

[2] Chair of Smart Architecture Technology, Eindhoven University of Technology, The Netherlands

[3] College of Environment + Design, University of Georgia, Georgia

* Corresponding author: Pai Liu (pail@dlut.edu.cn)

Abstract: With the accelerated pace of global aging, the issue of health in old age has gained widespread attention in all sectors of society. The natural environment has been shown to be an effective way to improve the physical and mental health of older people. However, different natural environments may affect older adults in different ways. Therefore, using virtual reality, this study assessed the healing effects of different natural environments based on the environmental preferences of Chinese older individuals. The study was conducted in an elderly city in northern China, and 65 participants over 60 years old were recruited. The results showed that simple and bright natural environments were preferred by older adults, with the forest being the most acceptable scene. In addition, older adults in poorer health experience greater therapeutic benefits in natural settings, which is more pronounced in the older age group >75.The results of thise study illustrate the extent to which different types of older individuals are adapted to different natural environments, and the resulting conclusions may inform future research and design regarding healthcare environments.

Keywords: Natural Environments, Older Individuals, Mental Restoration, Virtual Reality

1. Introduction

1.1 Natural environment promotes mental health in older individuals

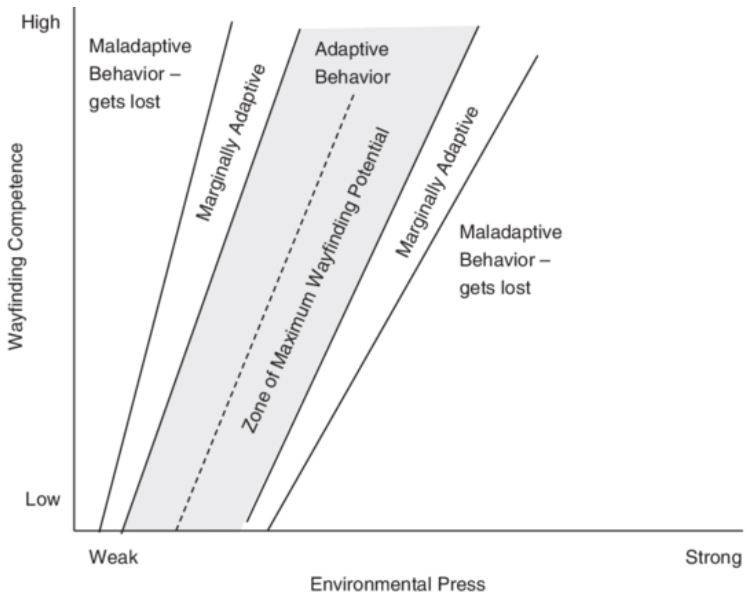
The natural environment has been found to reduce stress and anxiety, promoting mental health and well-being. As elucidated by the Attentional Restoration Theory (ART) and the Stress Recovery Theory (STR), ART suggests that exposure to natural environments facilitates cognitive restoration through the involuntary engagement of attention (Kaplan et al. 1989)., while STR highlights the stress-reducing capacity of natural surroundings, which can enhance positive emotions (Ulrich, 1991). Extensive research has confirmed that older adults can effectively enhance their physical and mental well-being, restore attention, and improve cognitive function by viewing natural landscapes. (Chan et al., 2020; Lovell et al., 2014a, 2014b). As older adults experience declines in physical functioning, their ability to perceive and adapt to their surroundings gradually decrease. Different natural environments impose varying levels of environmental stress, thereby influencing the therapeutic effects on older individuals (Lawton, 1980). Considering the limited physical abilities and mobility of older adults, this study replicated various types of natural environments using virtual reality (VR) technology to compare the efficacy of different natures.

Environment, composed of "physical and social features of people's lives," stands as one of the most influential factors affecting human life. Barton and Grant (2006) identified neighborhood/community, buildings, and the natural environment as determinants of older individuals' health and well-being. With more research emerging, mounting evidence suggests that the natural environment plays a crucial role in promoting physical and mental recovery, as well as emotional regulation (Barnett et al., 2018; Gobbens & van Assen, 2018; Groenewegen et al., 2006; Q He et al., 2021). Cecily et al. (2006) demonstrated that exposure to natural environments can alleviate physiological sub-health conditions, increase lifespan, and reduce mortality rates. Laboratory and clinical studies have found that observing natural environments can lead to significant restorative effects, with positive changes observed in blood pressure, cardiac activity, muscle tension, and brainwave activity of participants (Grinde & Patil, 2009; Ulrich, 1991, 1981). In conclusion, contact with natural environments plays a crucial role in people's physical and mental recovery, including with older adults.

1.2 Healing effects for older individuals and the Environmental Press Model

In 1973, American psychologist M. Powell Lawton proposed the Environmental Press Competence Model to explain individuals' adaptability to different environmental pressures (Lawton, 1986.). This model suggests that an individual's adaptability is influenced by two main factors: environmental pressure and individual competence (i.e., the individual's level of adaptation). Environmental pressure refers to the impact of the external environment on individuals' behavior and functioning, which can be physical, social, or psychological. Individual competence encompasses factors such as physical health, cognitive abilities, and psychological states. When an individual's competence matches the environmental pressure, optimal adaptability is achieved. (Annear et al., 2014) Choosing suitable natural environments is of great significance for the rehabilitation and mental balance of older individuals.

Figure 1. Environmental Press-Competence Model (Lawton, 1986)



1.3 Barriers prohibiting older individuals from viewing nature

In practical caregiving environments, older individuals face challenges in establishing effective connections with natural surroundings due to their declining mobility. On a personal level, mobility impairment, lack of strength, fear of falling, pain, and medication usage can affect an individual's ability and desire to engage in outdoor activities (Falvey et al., 2019; Helvik et al., 2014; Jerez-Roig et al., 2017). On a physical level, the lack of accessible infrastructure and high demands of weather/seasonal conditions are additional barriers restricting short-distance travel (CHENG Hanbei et al. 2021). In-home caregiving, there are many difficulties in increasing older individuals' exposure to nature. According to surveys, over 75% of older individuals in China reside in houses over 20 years old, which often suffer from issues such as excessively high floors and lack of elevators (J. Dunn, 2000). Additionally, there's a scarcity of natural landscapes within residential areas, which predominantly consist of brick, stone, and asphalt pavements. The lack of outdoor environments and limited accessibility exacerbate older individuals' mental health problems by hindering effective exposure to outdoor environments (Estabrooks et al., 2015; Evans, 2003; Zhang et al., 2019).

1.4 Application and value of virtual reality technology

Virtual reality technology was first applied in gerontology research in the early 2000s, primarily due to its ability to overcome the strict control of physical environments, addressing a long-standing challenge in gerontological research. In current research, the use of virtual reality typically focuses on the physical rehabilitation of older individuals and psychological issues caused by physical illnesses and social barriers. Nor-Wan Shamsuddin et al. (2011) demonstrated the feasibility of virtual reality technology in the early detection and treatment of Alzheimer's disease. Appel and Appel (2015) showed that immersive virtual reality using head-mounted displays (HMDs) is a feasible and safe method for providing beneficial experiences to older individuals with mobility, sensory, and/or cognitive impairments by allowing them to view a set of nature-based 360-degree real-life videos. These studies reveal the potential of using VR technology as a means of providing older individuals with opportunities to connect with nature, thereby promoting their positive emotions.

2. Methods

This study, which was approved by the Institutional Review Board (IRB) through a blinded review process, used virtual reality (VR) technology to present different types of nature scenes to avoid the problem of reduced accessibility for older adults due to physical limitations, and to assess differences in the psychological healing effects of different nature scenes on older adults. Participants were aged 60 years or older and were randomly recruited from the community, excluding older people with infectious diseases or severe mobility impairments. The experiment used the HTC Focus 3 VR headset as the device and the VR application Nature Treks. The app offers nine different experiential landscapes, including moonlit night, savannah, beach, grassland, cosmos, winter snowy day, deep sea, autumn, and sunset (Figure 2). Physiological data such as Attention, Meditation, and heart rate were collected during the experiment, and a short interview using the Perceived Resilience Scale was conducted at the end of the experiment to understand participants' perceptions of the experiment.

Figure 2. Scenarios used for VR Experiment

2.1 VR experiment

The VR experiment was conducted in an open outdoor area far from the road to ensure a quiet environment with minimal interference factors and higher physical adaptability among older participants. The experiment was conducted individually for each participant. After arriving at the experimental site at the scheduled time, the following procedures were carried out during the experiment (Figure 3).

(1) Researchers invited participants to sit on chairs. The purpose and process of the study were explained to the participants. The study proceeded only after participants agreed to participate. After putting on the equipment, participants were asked to close their eyes and rest for ten minutes. Researchers recorded physiological data for one minute during this period.

(2) Researchers assisted participants in wearing the virtual reality headsets and introduced the operation of the virtual reality program used in the study. Participants had three to five minutes to familiarize themselves with the equipment.

(3) The program's homepage displayed nine different scenic landscapes. Participants were asked to select three scenes and inform the researchers of their choices.

(4) Participants entered the first selected scene and experienced it for three minutes. Researchers recorded physiological data for one minute during the experience. This process was repeated three times.

(5) After the experience, participants removed the virtual reality headsets and closed their eyes to rest for ten minutes. Researchers recorded physiological data for one minute during this period. Subsequently, the sensors were removed.

(6) Researchers conducted a brief semi-structured interview with participants, asking about their feelings regarding the virtual reality experience and their preferences for the landscapes displayed in virtual reality. Participants also completed the PRS questionnaire.

Figure 3. Experiment with participants (pictures of older adults)

2.2 Measurement

2.2.1 Survey-Perceived Restorativeness Scale

The survey included two parts consisting of demographic questions and the Perceived Restorativeness Scale (PRS). PRS collected the perceptions of restorative qualities of the selected environments displayed in virtual reality. The PRS was developed from the Attention Restoration Theory proposed by Kaplan. It transformed Kaplan's four restorative factors into four subscales including “Being Away,” “Fascination,” “Coherence (refers to extent),” and “Compatibility.” The scale includes 26 items which are categorized into the four subscales to measure the restorative quality of environments. Participants rate the degree to which the supplied statement accurately depicts their experiences in the particular environment on a 7-point scale (0 = Not at all; 6 = Fully).

2.2.2 Data Analysis

A regression model and fixed factor analysis were applied to analyze the demographic data and PRS data collected in the survey. The overall PRS score and the estimated average score were calculated for each category. The PRS scenario and four recovery factors were defined as two fixed factors. The estimated heart rate was used as a supplement to explain the correlation between perceived recovery and different scenarios. An analysis was also conducted on interview data and open-ended questions that required displaying expected scenarios in virtual reality through topic coding.

3. Results and analysis

3.1 Participant characteristics

The initial sample comprised 68 older participants; however, the raw data collected by the sensors included missing values (n=3). After removing these missing values and retaining only valid data, the final sample included 65 older participants (35 females), with an average age of 69 years (M = 69.28). In terms of educational level, the majority of participants (n=38, 58.5%) had received education up to or below junior high school but possessed literacy skills; 18 individuals (27.7%) had completed high school education; and, 9 individuals (13.8%) had completed undergraduate education. Regarding health status, most participants were physically healthy (n=40, 61.5%), but 25 participants (38.5%) were still suffering from health issues. Regarding citizenship and living arrangements, most participants were married and cohabiting with their spouses (n=56, 86.2%), 9 individuals (13.8%) were widowed and living alone, but all participants (n=65, 100%) had descendants. Additionally, through questionnaire surveys and interviews, it was found that 97% of participants had no prior experience with VR devices before the experiment. Of the participants, 91% expressed a willingness to engage in

VR experiences again after the experiment, while only 6 participants expressed a reluctance to engage in VR experiences again. Their reasons were all related to experiencing mild dizziness during the experiment.

Table 1. Demographic information of participants

Total sample size		65	100%
Gender	Male	30	46%
	Female	35	54%
Age	60-74	53	82%
	75-89	12	18%
Education level	Junior school and below	38	58%
	High school	18	28%
	Undergraduate course	9	14%
Health	Health	40	62%
	Unhealthy	25	38%
Marital status	Married	56	86%
	Bereaved	9	14%
VR experience	Having VR experience	2	3%
	No VR experience	63	97%
Participating in VR again	Willing to participate	59	91%
	Refuse to participate	6	9%

3.2 Regression analysis results

Regression analyses showed significant associations between changes in subjects' scene choice, attention, heart rate, and health status and PRS scores. The scene variable showed a significant negative effect (coefficient = -0.064, p < 0.001). Similarly, the attention variable showed a significant negative effect (coefficient = -0.042, p < 0.001). In contrast, the heart rate (coefficient = 0.104, p < 0.001) and health variables (coefficient = 0.041, p < 0.001) showed significant positive effects. These findings provide valuable insights into the effects of the variables on the mean PRS scores, particularly for scene, attention, heart rate, and health.

Table 2. Regression Model of Physiological Responses

Coefficients[a]

	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	5.680	0.067		84.298	0.000
HR	0.009	0.001	0.104	11.155	0.000
Scene2	-0.024	0.003	-0.064	-6.925	0.000
Attention	-0.001	0.000	-0.042	-4.504	0.000
Health	0.070	0.016	0.041	4.466	0.000
Meditation	0.000	0.000	-0.004	-0.399	0.690

Dependent Variable: Score

3.3 Statistics based on PRS scores, Attention, and HR for different subgroups

Based on the different selected environments (S1 to S9), the average scores and standard deviations of the Perceived Restorativeness Scale (PRS) varied accordingly (Table 2). Feedback on the scenes also varied significantly based on the age and health conditions of the older participants. Overall, the average scores ranged from 5.830 to 6.465, indicating a moderate to high level of perceived restorativeness in the environments. Regarding health conditions, the average scores for healthy older participants ranged from 5.830 to 6.613, while the average scores for those with illnesses ranged from 5.649 to 6.354. This suggests that perceived restorativeness varies depending on health conditions, with lower PRS average scores for older participants with illnesses. However, Attention and HR values were higher, and physiological data fluctuations across different scenes were more pronounced compared to healthy older participants.

Table 3. Means and standard deviation across measures with varying VR environments

	S1 Moon Night		S2 Wild Savanna		S3 Tropical Beach		S4 Deciduous Forest		S5 Outer Space	
Selected times	4		26		20		44		9	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Overall	5.830	0.497	6.144	0.862	6.214	1.045	6.335	0.633	6.047	0.896
Health										
Health	5.830	0.497	6.005	1.024	6.137	1.199	6.355	0.533	6.219	0.966
Unhealth	0.000	0.000	6.307	0.578	6.354	0.657	6.303	0.760	5.649	0.527
Age										
60-74	5.597	0.336	6.100	0.878	6.101	1.130	6.290	0.581	5.994	0.930
75-89	6.526	0.000	6.676	0.317	6.679	0.261	6.478	0.760	6.526	0.000
Category										
Coherence	7.000	0.000	6.629	0.833	6.696	0.906	6.540	1.365	6.749	0.752
Compatibility	5.451	0.609	5.735	1.413	5.857	1.362	6.093	0.904	5.557	1.676

	S6 Snowy Glade		S7 Underwater Deep		S8 Autumn Mountains		S9 Sunset Forest		Total	
Selected times	22		33		33		4		195	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Overall	6.465	0.518	6.133	0.892	6.039	0.795	5.271	0.865	6.183	0.819
Health										
Health	6.613	0.335	6.163	0.946	5.864	0.837	5.271	0.865	6.152	0.885
Unhealth	6.302	0.625	6.049	0.716	6.214	0.709	0.000	0.000	6.233	0.695
Age										
60-74	6.404	0.525	6.049	0.915	5.898	0.809	5.271	0.865	6.096	0.843
75-89	6.686	0.425	6.742	0.270	6.628	0.328	0.000	0.000	6.607	0.506
Category										
being away	6.791	0.287	6.692	0.536	6.506	0.622	6.448	0.358	6.649	0.600
fascination	6.316	0.841	6.015	1.205	5.652	1.221	4.024	1.348	5.956	1.176
Coherence	7.000	0.000	6.907	0.317	6.870	0.510	7.000	0.000	6.768	0.840
Compatibility	6.133	1.048	5.531	1.393	5.781	1.164	5.150	1.413	5.819	1.253

In terms of age groups, individuals aged 60 to 74 years had PRS mean scores ranging from 5.597 to 6.404. In most scenarios, participants with illnesses exhibited higher Attention and HR values compared to healthy participants, especially in Scenario S5. Conversely, individuals aged 75 to 89 years had mean scores ranging from 6.478 to 6.742, indicating differences in perceived restorativeness among different age groups. Older participants perceived higher restorativeness of the scenarios, but their Attention and HR average values varied significantly depending on the selected scenario. This may suggest that older age groups are more sensitive to scene feedback, with healthy participants generally exhibiting higher average Attention and HR values compared to those with illnesses. Furthermore, the average scores for different categories (fascination, being away, coherence, and compatibility) ranged from 4.024 to 7.000, indicating variations in perceived restorativeness based on different aspects of the environment.

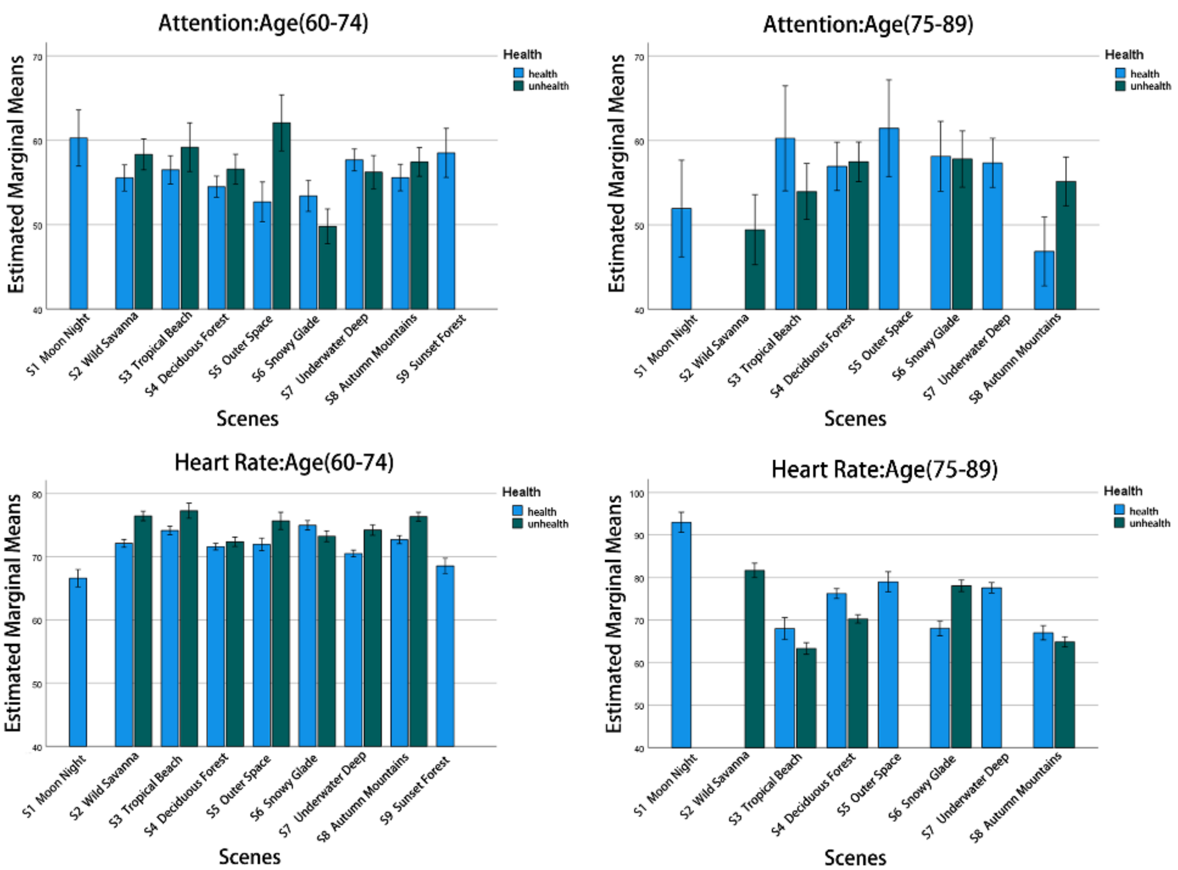


Figure 4. Means of physiological responses in older participants with different health conditions based on different age groups

4. Discussion

4.1 Older individuals of advanced age tend to exhibit heightened environmental sensitivity, resulting in higher perceived restorativeness scores for the environment. This phenomenon is particularly pronounced among older individuals with poorer health conditions

The research findings indicate that older adults tend to give higher perceived restorativeness scores for the environment and exhibit more pronounced physiological fluctuations in response to different environments. Additionally, there is a clear association between health status and environmental perception. Older adults with poorer health conditions show a more positive perception of environmental restorativeness, suggesting that they may be more sensitive to their surroundings and therefore give higher ratings. In contrast, the correlation between health status and environmental perception is weakened among younger participants. These findings suggest that when designing facilities or environments for older individuals, it is crucial to consider the influence of both health status and age factors on environmental perception to promote their perceived restoration and overall well-being.

4.2 Coherent scenes are more readily accepted by older adults, with forest environments being the most preferred.

Coherence refers to the interconnection between elements within an environment. In this study, higher coherence implies greater consistency among elements within a scene. S4 Deciduous Forest, S6 Snowy Glade, and S8 Autumn Mountains exhibit limited environmental variation, characterized by large contiguous areas with similar features. The high consistency of landscape elements suggests reduced environmental stimuli. These environments are not perceived as chaotic or confusing (Alyan et al., 2021), eliciting higher perceived restorativeness (PRS) ratings from participants compared to other scenes.

Among the statistical results of scene selection, S4 Deciduous Forest was the most frequently chosen scene, significantly surpassing the selections of other scenes. This indicates that forest environments may be more congruent with the environmental preferences of older adults. Physiological data analysis further indicates that this scene exhibits high and stable restorative levels, with minimal influence from participants' health status and age variations. Interview records from the experiment suggest that this preference may partly be attributed to the frequent exposure of older adults to forest environments throughout their lives, potentially associating them with positive memories and experiences, thereby leading to a higher affinity and adaptation to forest environments and resulting in better healing effects (Mysyuk & Huisman, 2020).

4.3 Scenes with low luminance are generally not accepted, but scenes far removed from everyday life, such as outer space, may attract older adults' attention

Over 90% of older adults actively avoided scenes with low luminance, including S1 Moon Night, S5 Outer Space, and S9 Sunset Forest. Among them, S1 Moon Night and S9 Sunset Forest closely resemble natural scenes but with dim lighting, causing older adults to perceive these environments as stressful and less safe. However, the physiological results for S5 Outer Space were highly positive, with older adults with weaker health conditions experiencing higher restoration effects. However, only 9 older adults chose to experience S5 Outer Space, all aged below 75 years, possibly indicating a decreased acceptance of novel stimuli with increasing age. Therefore, the acceptance of such unique environments as therapeutic environments for older adults has certain limitations compared to other environments.

4.4 Research limitations

Due to issues such as the limited mobility of older adults and the construction costs associated with physical environments, the study used VR to test the efficacy of different environments. However, virtual reality primarily stimulates the visual and auditory senses to simulate natural environments, leading to some differences compared to real-world environments. The study results reported nearly 10% of participants feeling uncomfortable, such as dizziness with device, which may have influenced the data outcomes. In addition, the sample size of the study was limited and concentrated in the northeastern region of China, indicating an impact of geographical factors.

5. Conclusion

This study discusses the environmental preferences of Chinese older individuals and the recuperative effects of different natural environments using nine distinct virtual reality scenes. The results indicate that older senior participants exhibit higher sensitivity to their environment and prefer brighter, simpler natural scenes, with forest environments being the most readily accepted. Such scenes have positive and stable recuperative effects on older individuals, with older adults with poorer health conditions experiencing higher levels of restoration, a phenomenon particularly pronounced among older senior participants. Unique scenes such as outer space were actively avoided by 90% of the older individuals, but a small percentage who chose to experience such scenes provided relatively high positive feedback. Therefore, forest environments may provide the most stable healing effects of those environments tested in this study and are the most easily accepted by older individuals compared to other environments. The results of this study can serve as a reference for future research and design of landscape therapy for older individuals. Future research could delve into a more detailed exploration and study of the efficacy of landscape elements

References

Alyan, E., Combe, T., Awang Rambli, D. R., Sulaiman, S., Merienne, F., & Muhaiyuddin, N. D. M. (2021). The Influence of Virtual Forest Walk on Physiological and Psychological Responses. International Journal of Environmental Research and Public Health, 18(21), Article 21. https://doi.org/10.3390/ijerph182111420

Annear, M., Keeling, S., Wilkinson, T., Cushman, G., Gidlow, B., & Hopkins, H. (2014). Environmental influences on healthy and active ageing: A systematic review. Ageing & Society, 34(4), 590–622. https://doi.org/10.1017/S0144686X1200116X

Barnett, A., Zhang, C. J. P., Johnston, J. M., & Cerin, E. (2018). Relationships between the neighborhood environment and depression in older adults: A systematic review and meta-analysis. International Psychogeriatrics, 30(8), 1153–1176. https://doi.org/10.1017/S104161021700271X

Chan, J. Y. C., Chan, T. K., Wong, M. P. F., Cheung, R. S. M., Yiu, K. K. L., & Tsoi, K. K. F. (2020). Effects of virtual reality on moods in community older adults. A multicenter randomized controlled trial. International Journal of Geriatric Psychiatry, 35(8), 926–933. https://doi.org/10.1002/gps.5314

Cheng, H., Liu, Y., Tian, M., & Li, Z. (2021). The Impact of "Residential Instability" on the Health of Floating Population in Major Chinese Cities: A Study. Geographical Research, 01, 185-198.

Estabrooks, C. A., Hoben, M., Poss, J. W., Chamberlain, S. A., Thompson, G. N., Silvius, J. L., & Norton, P. G. (2015). Dying in a Nursing Home: Treatable Symptom Burden and its Link to Modifiable Features of Work

Context. Journal of the American Medical Directors Association, 16(6), 515–520. https://doi.org/10.1016/j.jamda.2015.02.007

Evans, G. W. (2003). The built environment and mental health. Journal of Urban Health: Bulletin of the New York Academy of Medicine, 80(4), 536–555. https://doi.org/10.1093/jurban/jtg063

Falvey, J. R., Gustavson, A. M., Price, L., Papazian, L., & Stevens-Lapsley, J. E. (2019). Dementia, Comorbidity, and Physical Function in the Program of All-Inclusive Care for the Elderly. Journal of Geriatric Physical Therapy, 42(2), E1. https://doi.org/10.1519/JPT.0000000000000131

Gobbens, R. J. J., & van Assen, M. A. L. M. (2018). Associations of Environmental Factors With Quality of Life in Older Adults. The Gerontologist, 58(1), 101–110. https://doi.org/10.1093/geront/gnx051

Grinde, B., & Patil, G. G. (2009). Biophilia: Does Visual Contact with Nature Impact on Health and Well-Being? International Journal of Environmental Research and Public Health, 6(9), Article 9. https://doi.org/10.3390/ijerph6092332

Groenewegen, P. P., van den Berg, A. E., de Vries, S., & Verheij, R. A. (2006). Vitamin G: Effects of green space on health, well-being, and social safety. BMC Public Health, 6(1), 149. https://doi.org/10.1186/1471-2458-6-149

Helvik, A.-S., Engedal, K., Benth, J. Š., & Selbæk, G. (2014). A 52 month follow-up of functional decline in nursing home residents – degree of dementia contributes. BMC Geriatrics, 14(1), 45. https://doi.org/10.1186/1471-2318-14-45

J. Dunn. (2000, May). Housing and Health Inequalities: Review and Prospects for Research | Semantic Scholar. https://www.semanticscholar.org/paper/Housing-and-Health-Inequalities%3A-Review-and-for-Dunn/93867d75e8d1b3f97af812bc96d08cce179f05a3

Jerez-Roig, J., Ferreira, L. M. de B. M., Araújo, J. R. T. de, & Lima, K. C. (2017). Functional decline in nursing home residents: A prognostic study. PLOS ONE, 12(5), e0177353. https://doi.org/10.1371/journal.pone.0177353

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. Cambridge ; New York : Cambridge University Press. http://archive.org/details/experienceofnatu00kaplLawton, M. P. (Mortimer P. (1980). Environment and aging. (No Title). https://cir.nii.ac.jp/crid/1130282269449460736

Lovell, R., Wheeler, B. W., Higgins, S. L., Irvine, K. N., & Depledge, M. H. (2014a). A Systematic Review of the Health and Well-Being Benefits of Biodiverse Environments. Journal of Toxicology and Environmental Health, Part B, 17(1), 1–20. https://doi.org/10.1080/10937404.2013.856361

Lovell, R., Wheeler, B. W., Higgins, S. L., Irvine, K. N., & Depledge, M. H. (2014b). A Systematic Review of the Health and Well-Being Benefits of Biodiverse Environments. Journal of Toxicology and Environmental Health, Part B, 17(1), 1–20. https://doi.org/10.1080/10937404.2013.856361

Mysyuk, Y., & Huisman, M. (2020). Older people's emotional connections with their physical urban environment. Cities & Health, 4(1), 25–30. https://doi.org/10.1080/23748834.2019.1693190

Q He, HT Chang, CD Wu, & J Ji. (2021). Association between residential greenspace structures and frailty in a cohort of older Chinese adults | Communications Medicine. https://www.nature.com/articles/s43856-022-00093-9

Ulrich. (1991). Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology, 11(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Ulrich, R. S. (1981). Natural Versus Urban Scenes: Some Psychophysiological Effects. Environment and Behavior, 13(5), 523–556. https://doi.org/10.1177/0013916581135001

Zhang, H., Wang, Z. H., Wang, L. M., Qi, S. G., & Li, Z. X. (2019). [Study on activities of daily living disability in community-dwelling older adults in China]. Zhonghua Liu Xing Bing Xue Za Zhi = Zhonghua Liuxingbingxue Zazhi, 40(3), 266–271. https://doi.org/10.3760/cma.j.issn.0254-6450.2019.03.003

3 Healthy cities & nature-based living (with care) concepts: **Conference paper**

Feel the natural work rhythm

Marleen van Beuzekom[1*], Liesbet Rabbinge[1], Masi Mohammadi[1,2]

[1] HAN University of Applied Sciences, The Netherlands

[2] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Marleen van Beuzekom (M.vanBeuzekom@han.nl)

Abstract: This explorative study examines how a biophilically-designed workplace influences the time management practices of higher education lecturers based on their own perceptions and observed behaviors. Biophilic design, which integrates natural elements into the built environment, is proposed as a potential solution to enhance cognitive performance and reduce workplace stress. Utilizing a human-centered design framework, the study developed two distinct work environment prototypes, "Forrest" and "Sea." Each prototype incorporates visual and auditory cues from natural landscapes. Conducted at the HAN University of Applied Sciences, the research employed a mix of qualitative methods, including expert interviews, context mapping, and usability testing, to assess the effectiveness of these environments.
Results indicate that while the biophilic setups increased focus and relaxation, the environmental cues designed to signal break times were not consistently effective, suggesting a need for clearer and more intuitive design adjustments. Future studies should explore the customization of environmental cues and investigate the long-term effects of biophilic design on academic productivity and mental health.

Keywords: Healthy workplace, Time management, Higher education lecturers, Biophilic design, Burn-out

1. Introduction

In higher education, faculty members confront substantial challenges as they navigate their multifaceted roles in teaching, research, communication, and administration. Each of these roles requires high cognitive engagement and frequent task-switching, often leading to significant time management issues. Existing research underscores the severe consequences of poor time management, linking it to increased stress, reduced job satisfaction, and higher burnout rates (Aeon & Aguinis, 2017, TNO-2020.). Moreover, the introduction of new communication technologies has further complicated these challenges by increasing the frequency of interruptions. Such disruptions often lead to sporadic and insufficient break patterns, exacerbating cognitive overload and diminishing overall productivity (Saini & Monga, 2008, Shalawadi et al., 2021). The difficulty in maintaining focus due to these interruptions translates into increased work pressure, creating a vicious cycle that impacts educators, efficiency and well-being.

Traditional methods and tools designed to improve time management, such as digital applications like DeskTime and Toodledo, or structured time management training, often fall short. They typically focus on organizing tasks without addressing the broader environmental and psychological factors that significantly influence faculty behavior in academic settings. These tools prioritize structural organization over the qualitative aspects of the work environment, which are crucial for affecting daily routines and managing stress levels effectively (Shalawadi et al., 2021).

In response to these inadequacies, biophilic design emerges as a promising solution by integrating natural elements into the built environment. This approach leverages the restorative effects of nature to enhance cognitive performance, reduce stress, and improve overall well-being (Kellert et al., 2008). Empirical studies have shown that interactions with natural environments can help replenish depleted mental resources, facilitating better focus and more effective time management (Kaplan, 1995) (Ryan et al., 2014) However, the specific application of biophilic principles to academic settings, especially in managing the unique temporal demands of teaching and research, remains underexplored. This gap in the literature underscores the need for research that directly examines the impact of biophilic design on time management within the context of higher education where burn-out occurs above average in the sector of educational professionals (24% in education, compared to 17% on average (TNO, n.d.). This study aims to address this deficiency by exploring how a biophilically-designed workplace influences the time management practices of higher education teachers. Collaborating with teachers and students, we developed a workstation, Feel the natural work rhythm, that utilizes biophilic design elements to enhance time management effectively. This research delves into how biophilic environments impact educators' ability to manage their work schedules, handle task switching, and take effective breaks. Biophilic environments have been successful in offices, to reduce stress, and gain productivity by placing plants, adding running water, creating natural patterns, using natural materials and mimicking daylight. Effects found are lower stress levels and increased productivity (Aristizabal et al., 2021).

Guided by the question: "How does a biophilic-designed workplace specifically influence the time management practices of higher education lecturers, according to their own perceptions and observed behaviors?" This research aims to contribute to the fields of educational workplace design. By offering tangible co-creative design solutions, this study promotes productivity and well-being among educators through the integration of natural elements. The anticipated findings are expected to provide practical implications for enhancing the daily work routines of higher education faculty, thus improving both personal and institutional outcomes.

2. Methods

2.1 Empathic Design Framework

To systematically explore the influence of a biophilical-designed workplace on the time management and stress levels of higher education lecturers, this study which took place from October 2021 until October 2022, employs the Empathic Design Framework (Mohammadi, 2017). This methodology is structured into four distinct phases—Explore, Translate, Elaborate, and Validate—each designed to progressively refine our understanding of users' needs and develop solutions that are both innovative and practical (Figure 1). The integration of these phases ensures a comprehensive approach to addressing the research question, linking the development of practical design solutions directly to the exploratory and empirical insights gained throughout the study.

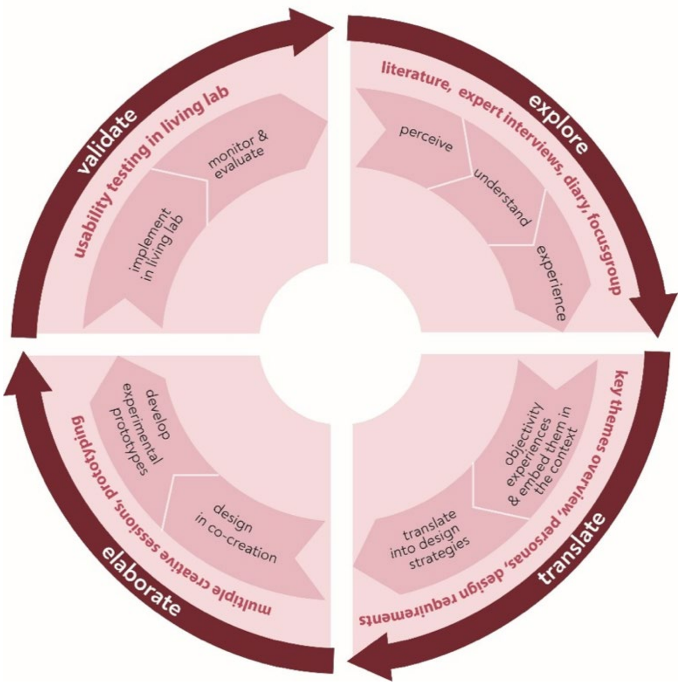


Figure 1. To ensure a user-centered approach in all aspects of the research, the study utilized an Empathic Design Framework.

2.2 Exploration phase

The initial phase involved a thorough exploration of existing literature on biophilic design and its effects on workplace productivity and mental health, directly addressing the gap identified in the introduction regarding the underexplored application of biophilic design in academic settings. Expert interviews focused on the work experiences of higher educational lecturers, work related stress, their current work environment and a balance between effort and relaxation, these were conducted with a burnout coach and a project leader for healthy work environments, alongside interviews with two lecturers who had experienced burnout, providing insights into the specific challenges faced in educational settings. Additionally, context mapping sessions (Visser et al., 2005), involving 18 participants who kept detailed diaries of their daily work experiences, were facilitated. This was complemented by an online focus group session with three participants, to ensure an engagement with users' needs and experiences', aspects that came from this is that lecturers have issues with time, like to work together, get fulfillment out of helping students, like to be challenged and are inspired by nature, themes are summarized and can be found in figure 2. These foundational findings informed the hypotheses that biophilic design could improve time management and reduce stress, guiding the subsequent design of the "Forrest" and "Sea" prototypes.

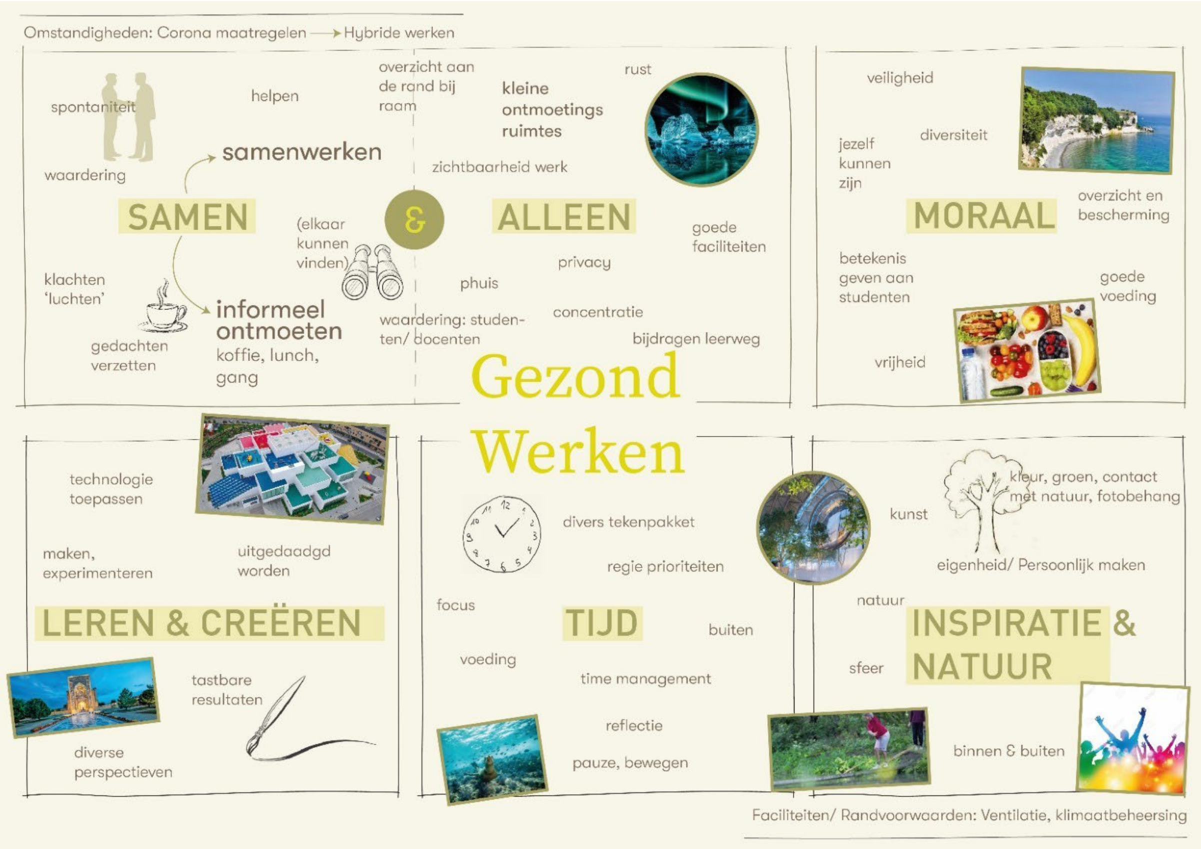


Figure 2. Insights from the Exploration Phase

2.3 Translation Phase

This phase is critical as it translates the theoretical framework and user insights into tangible designs that can be interactively experienced by the participants. Insights from the exploration phase were distilled into a visual mood board that categorized themes and identified core needs (figure 2). This led to the development of a specific Design Assignment, which outlined the primary design requirements and resulted in the creation of personas representing the user base. This phase bridged the gap between empirical data and actionable design criteria, ensuring that the solutions developed were tailored to user-specific contexts and directly informed by the initial exploration findings.

2.4 Elaboration Phase: Development of the Prototypes

The Elaboration phase involved co-creative brainstorming sessions (3 sessions, involving 10 lecturers, between January and March 2022) where ideas generated from the Translation phase were created, evaluated, discussed and developed into conceptual designs for two distinct environments: Forrest and Sea. The main reason to choose for these two landscapes is that both are recognizable Dutch landscapes that are releasing stress in different ways. The Natural workplaces are an integration of the Pomodoro working cycle into Natural work environments, for the prototypes following a timeframe of half an hour with a 5 minute break (figure 3).

- Forrest setup: Designed to emulate a forest-like environment within an indoor workspace (figure 4a), this prototype incorporated several biophilic elements:
    - Visual Elements: This included the use of greenery and imagery that mimic a forest landscape to create a serene and naturalistic setting. A fluttering butterfly projection was also included to add dynamic natural movements to the environment.
    - Auditory Elements: Sounds of the forest, such as rustling leaves and bird calls, were played on headphones to enhance the sensory experience and foster a calming atmosphere.
    - Interactive Cues: To signal break times aligned with the Pomodoro technique, subtle changes in the environment were introduced. For example, the intensity of the forest sounds and the movements of the butterfly projection increased as the work interval neared its end, subtly prompting the user to prepare for a break.
- Sea setup: The Sea setup aimed to replicate the calming effects of the ocean and used different sensory modalities (figure 4b):
    - Visual and Auditory Elements: The setup included visuals and sounds of sea waves. The visual component simulated the ebb and flow of tides, while the accompanying sounds reinforced the relaxing atmosphere of a seaside environment.
    - Tactile Elements: To mimic the feeling of the sea breeze, gentle wind effects were integrated into the setup, following a natural irregular pattern.
    - Biofeedback Integration: The rhythm of the wave sounds and visual movement was designed to match the breathing patterns of the user, providing biofeedback aimed at promoting relaxation. This feature was particularly innovative as it actively engaged the user's breathing rhythm, encouraging deeper, more relaxed breathing patterns during break periods.

Figure 3. Pomodoro working cycle for the test setups.

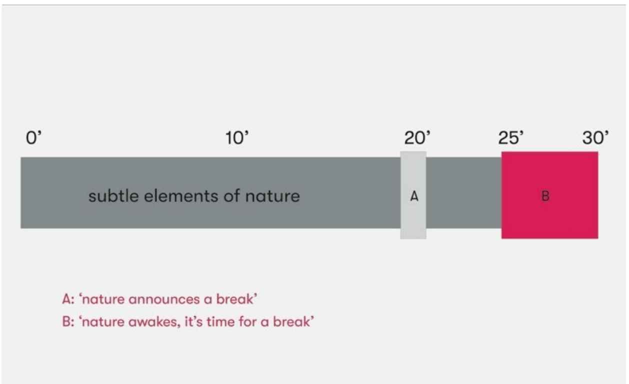
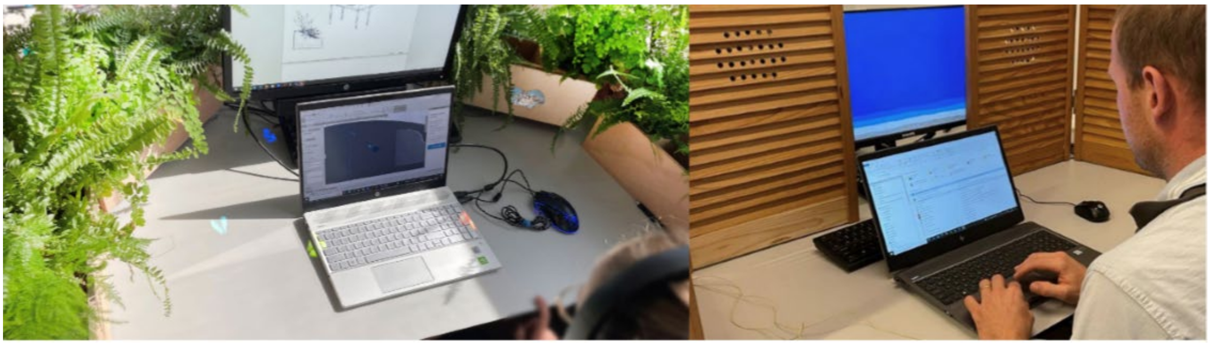


Figure 4. Test set-up at HAN University flex offices (Figure 4a 'Forrest', Figure 4b 'Sea').



2.5 Validation Phase

This final phase involved structured usability testing where the refined prototypes were evaluated in real-world settings at the HAN University of Applied Sciences' flex offices. Data were collected through direct observation of participants' interactions with the environments, semi-structured interviews to capture subjective experiences, and analysis of self-reported stress and productivity levels before and after the testing sessions. This structured approach was crucial for assessing the practical effectiveness of the design solutions and gathering detailed user feedback for future iterations. The usability testing for the Forrest and Sea prototypes provided substantial data through observations and participant feedback, directly reflecting these findings and feedback gathered during the testing phase.

By carefully documenting how data collection integrates into the Elaboration and Validation phases, the methodology not only ensures a comprehensive evaluation of the prototypes' effects but also supports the overall integrity of the research design, linking directly back to the stated aims and anticipated outcomes of the study.

3. Results and analysis

3.1 Analysis of findings

Before delving into the specific results from the prototype testing, it's crucial to acknowledge the foundational insights that shaped the research design. Initial phases of the study, including context mapping sessions and expert interviews, provided valuable perspectives on the challenges faced by educators in their work environments. These insights emphasized the importance of natural elements and subtle environmental cues in enhancing focus and reducing stress, the multi sensorial nature experience, the possibility to have social contact and withdraw oneself and space for mental and physical breaks. These foundational findings informed the hypotheses and subsequent design of the "Forrest" and "Sea" setups, guiding the exploratory focus of our usability testing.

This section now explores the impact of these prototypes on improving time management and reducing stress among higher education lecturers. Our approach incorporated a range of methods, including direct observations, semi-structured interviews, and analysis of self-reported stress and productivity levels before and after the testing sessions. This provided a robust framework for evaluating the effectiveness of biophilic design on workplace behavior and well-being.

Observational data and participants' feedback:

- **Forrest setup:** Participants reported a significant increase in relaxation and focus, attributed to immersive elements like rustling plants and ambient forest sounds. However, the cues intended to signal breaks—such as intensified rustling of plants and butterfly projections—were not consistently effective. For example, one participant noted, "The rustling leaves are calming, yet it's easy to ignore them when deeply focused on work."
- **Sea setup:** Utilizing visual and auditory cues that mimic the sea generally helped to reduce stress levels. Nonetheless, the abrupt introduction of voice-prompted breathing exercises was seen as disruptive. A participant commented, "The sound of the sea is supposed to be relaxing, but the abrupt voice for breathing exercises felt jarring."

We categorize the feedback of the participants in three categories:

- **Effectiveness of Environmental Cues:** Although aesthetically pleasing, the functionality of the setups in prompting breaks was inconsistent and not clear.
- **Cue Personalization:** Feedback highlighted strong interest in personalizing environmental cues to match individual preferences, underscoring the limitations of a one-size-fits-all approach in workspace design.
- **Transition Smoothness:** Participants suggested that transitions into break periods could be smoother for the Sea setup and clearer for the Forrest setup, emphasizing the need for enhancements in how cues are presented and changing over time.

Tables 1 and 2 detail the analysis of biophilic design elements based on the test setups. These tables categorize the design features, intended effects, positive and negative participant feedback, and their contributions to a healthy balance between working and recovery phases. Each table provides a structured summary of how different elements performed in the test environments, directly correlating with the feedback discussed above and evaluates how each design element contributes to creating a healthier balance between work and recovery phases, offering insights into their effectiveness in enhancing focus and managing stress.

Table 1. Detailed Analysis of Biophilic Design Elements from the 'Forrest' Setup

DESIGN FEATURE	INTENDED EFFECT	POSITIVE PARTICIPANT FEEDBACK	NEGATIVE PARTICIPANT FEEDBACK	CONTRIBUTION TO HEALTHY BALANCE
VISUAL ELEMENTS: **NATURAL GREEN FENCE, BUTTERFLY, VIEW TO BIRDS NEST**	Create a relaxing atmosphere, effect of being surrounded by nature	"Good, pleasant green surrounding me." "Movement gives a little feeling that you are in nature."	"I don't think it will take away stress."	Positively contributes to focus during work but unclear during recovery phases.
AUDITORY ELEMENTS: FOREST SOUNDS	Strengthen the effect of being surrounded by nature	"Sound helped to concentrate."	"Artificial. A sound that repeats itself, not related."	Enhances focus, but the repetitive nature could be distracting.
INTERACTIVE CUES: CHANGES IN VISUAL AND AUDITORY ELEMENTS	Signal break times aligned with the Pomodoro technique	"Sounds became different, more variation in sound. The butterflies got colours."	"Movement of the plants is not really noticeable."	Needs improvement; cues not effectively signaling break times, requiring clearer differentiation from the working phase.

Table 2. Detailed Analysis of Biophilic Design Elements from the 'Sea' Setup

DESIGN FEATURE	INTENDED EFFECT	POSITIVE PARTICIPANT FEEDBACK	NEGATIVE PARTICIPANT FEEDBACK	CONTRIBUTION TO HEALTHY BALANCE
VISUAL AND AUDITORY ELEMENTS: SEA WAVES	Create a relaxing atmosphere, effect of being at the sea	"Sound just enough to filter out noise, keeps noise out sufficiently." "I work with concentration here, through the headphones."	"Very soothing, but it also makes me sleepy."	Generally positive, but needs tuning to avoid sleepiness.

TACTILE ELEMENTS: WIND	Strengthen the effect of being at the sea	"I would find the wind suitable if there was more variety."	"Wind doesn't feel good in the face."	Mixed; the wind needs to be adjustable to suit individual preferences.
BIOFEEDBACK INTEGRATION	Provide biofeedback aimed at promoting relaxation	"Breathing exercise, normally suitable, but this was based on tension, which was not there."	"That I was suddenly given a breathing exercise. It came like a bombshell."	Needs significant refinement to ensure user comfort and autonomy.

3.2 Synthesis of Findings:

The detailed feedback from usability testing demonstrates that while biophilic design elements can significantly enhance relaxation and productivity, the mechanisms for signaling breaks require clearer differentiation and better alignment with natural human rhythms. The study's exploratory nature is reflected in the participant responses, which suggest that future design iterations should incorporate more direct and customizable interactions, enhancing both the aesthetic and practical functionality of workplace environments.

4. Discussion

The study's investigation into 'The Natural Work Rhythm' evaluated the effectiveness of a biophilic-designed workplace in enhancing time management and reducing stress, offering a comparison to traditional work environments. This evaluation was conducted with eight lecturers at the HAN University of Applied Sciences' Communication and Multimedia Design Academy, using two distinct setups: Forrest and Sea. These setups integrated natural elements and interactive technologies to explore their potential benefits. It must be mentioned that the following conclusions are based on exploratory research, which means that the effects of using the setups Forrest and Sea on reducing stress cannot be made solid and need follow-up research.

5. Conclusion

Participants in the Forrest setup experienced an enhanced sense of relaxation and improved concentration, appreciating the setup more positively than conventional workspaces. However, they noted that the natural cues meant to signal break times, such as rustling plants and butterfly projections, did not consistently capture attention or effectively initiate breaks. In the Sea setup, while the cues were perceived as clearer, the abrupt introduction of a voice-prompted breathing exercise was seen as too sudden, highlighting the need for smoother transitions into break periods.

The feedback from testing indicated that while the biophilic elements were aesthetically pleasing and contributed to a general sense of well-being, there was a critical need for the environmental cues intended to signal breaks to be more distinctive and clearly linked to their purpose. The feedback suggests a gap between the design intention and participant perception, highlighting the importance of designing distinct and interpretable cues that are not only natural and integrated but also unambiguously indicative of their functional role in time management and stress reduction. Reflecting participants' feedback, there is significant interest in exploring customization features that allow users to adjust environmental settings to their specific needs, including adjustable sound levels, variable lighting conditions, and customizable visual elements. The integration of biophilic design elements with the structured break schedule of the Pomodoro technique brought several benefits, including reduced stress levels and enhanced focus, facilitated by natural barriers and ambient sounds that minimized distractions. These elements also supported workplace interactions, allowing for conversations with colleagues without sacrificing productivity.

Nevertheless, the natural cues used to initiate breaks require further refinement to ensure they are noticeable without being disruptive. Future design iterations should focus on enhancing the clarity and intuitiveness of these cues for the Forest setup and implementing softer, more gradual transitions for break-initiating cues in the Sea setup, which could improve user receptiveness and comfort.

These findings lead to the following recommendations for future research:

- Developing clearer and more intuitive cues: Future designs should aim to create distinct and easily interpretable cues that not only fit naturally into their environment but also unmistakably indicate their intended purpose. Multi-sensory cues that combine visual, auditory, and possibly olfactory signals could be more effective in capturing attention and prompting necessary action in an inviting way.
- Exploring personalization in biophilic design: It is crucial to conduct further studies on the integration of personalization features that allow users to adapt environmental settings to their individual needs. This could include adjustable sound levels, lighting conditions, and the intensity of visual elements.
- Longitudinal studies on biophilic impact: Long-term studies are essential to provide deeper insights into the prolonged impacts of biophilic design on productivity and mental health, which could help to quantify long-term benefits and identify potential drawbacks or diminishing effects over time.

As biophilic design becomes increasingly integrated with technology, **ethical considerations** around privacy and user consent are paramount. Responsible data management, particularly when biometric data might be involved, must adhere to stringent ethical guidelines. Moreover, the technical integration of technology within biophilic designs requires meticulous refinement, focusing on developing multi-sensory cues that effectively capture attention and prompt action

without overwhelming users. Additionally, the impact of these designs on workplace culture and interpersonal interactions must be carefully evaluated to ensure they enhance individual well-being without isolating individuals or detracting from collaborative opportunities.
Further research is vital in advancing our understanding of how biophilic design can transform educational environments, enhancing them to be more conducive to health and productivity while fostering an engaging and sustainable workspace. This study advocates for a shift towards more sustainable and human-centered design practices in educational institutions, potentially influencing policy and design standards across the sector.

Acknowledgements

This research was funded by a SIA KIEM creative industry fund. Partners that contributed to this research are Schoots Architects and IJsfontijn experience creators. We would like to thank lecturers of HAN of different divisions and the students of HAN CMD and IPO that cooperated in this project. HAN housing provided space in the flex offices to install the test set-up.

References

Aeon, B., & Aguinis, H. (2017). It's About Time: New Perspectives and Insights on Time Management. Academy of Management Perspectives, 31(4), 309–330. https://doi.org/10.5465/amp.2016.0166

DeskTime | A Time Tracker For Both Remote And On-site Teams. (n.d.). Retrieved 19 April 2024, from https://desktime.com

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. Journal of Environmental Psychology, 15(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Kellert, S. R., Heerwagen, J. H., & Mador, M. L. (2008). Dimensions, elements, and attributes of biophilic design. Biophilic design: The theory, science, and practice of bringing buildings to life. http://ndl.ethernet.edu.et/bitstream/123456789/41518/1/95.pdf#page=19

Rede_Mohammadi_LR_2017_30_juni.pdf. (n.d.). Retrieved 19 April 2024, from https://pure.tue.nl/ws/portalfiles/portal/70373109/Rede_Mohammadi_LR_2017_30_juni.pdf

Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). BIOPHILIC DESIGN PATTERNS: Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment. International Journal of Architectural Research: ArchNet-IJAR, 8(2), 62. https://doi.org/10.26687/archnet-ijar.v8i2.436

Saini, R., & Monga, A. (2008). How I decide depends on what I spend: Use of heuristics is greater for time than for money. Journal of Consumer Research, 34(6), 914–922. https://doi.org/10.1086/525503

Shalawadi, S., Alnayef, A., Van Berkel, N., Kjeldskov, J., & Echtler, F. (2021). Rainmaker: A Tangible Work-Companion for the Personal Office Space. Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction, 1–13. https://doi.org/10.1145/3447526.3472032

TNO-2020-R11768.pdf. (n.d.).

Toodledo | Online To Do Lists, Task Manager, Note Taking & More. (n.d.). Toodledo. Retrieved 19 April 2024, from https://www.toodledo.com/

Visser, F. S., Stappers, P. J., van der Lugt, R., & Sanders, E. B.-N. (2005). Contextmapping: Experiences from practice. CoDesign, 1(2), 119–149. https://doi.org/10.1080/15710880500135987

3 Healthy cities & nature-based living (with care) concepts: **Conference paper**

Influential factors in window design on the mental health of older adults, a case study of Sistan region

Nima Ettehadi[1]*, Masi Mohammadi[2], Shore Shahnoori[2]

[1] Department of Art and Architecture, Islamic Azad University, Iran
[2] Chair of Smart Architecture Technology, Eindhoven University of Technology, The Netherlands

*Corresponding author: Nima Ettehadi (nima_ettehadi2000@yahoo.com)

Abstract: More than 90% of people's lives unfold within the confines of buildings, underscoring the pivotal role of house design quality in the health and well-being of its inhabitants. Research indicates that features like adequate daylight, proper ventilation, and desirable views in housing design can simultaneously bolster mental and physical health. The World Health Organization (WHO) defines health holistically as "a state of complete physical, cognitive, and social well-being and not merely the absence of disease or infirmity. Studies in health-related fields underscore the crucial role that windows play in buildings. For older adults, windows can serve as a gateway to the world, particularly for those who spend significant time at home. This research focuses on identifying indicators that affect the mental health of older individuals and examining how windows can enhance their mental health in the Sistan region. The research methodology involved a comprehensive review of texts and articles alongside the design of a questionnaire, which was developed using the Laoche method based on expert opinions. Analyses were conducted using the SECA analysis, a multi-objective nonlinear programming model. The research findings reveal that among all components involved in window design affecting the mental health improvement of elderly individuals in the Sistan region, the view and landscape exert the most significant influence. In contrast, window shape has a lesser impact.

Keywords: Window, Mental Health, Elderly, Sistan

1. Introduction

The rising trend of the elderly population underscores the increasing importance of their health. Globally, the proportion of individuals aged 60 years and above is projected to reach approximately 22% by 2050 (WHO, 2007). According to Iran's 1390 census, the country is home to 3.4 million elderly individuals aged 65 and above, constituting 5.7% of the total population. Demographic forecasts indicate that by 1430, the number of elderly individuals aged 65 and over in Iran will surge to 18 million, with their population share reaching around 20% (Sadeghi, 2013). In Iran, due to the significant increase in life expectancy in recent years, 60 years is considered the beginning of old age for retirement, and the provision of integrated elderly services and care is set to commence at this age.

Most individuals spend about 90% of their time inside buildings (Ampollini et al., 2029), so every building significantly impacts our daily lives. Overall, home design quality is a crucial factor in determining the health and well-being of its residents. Research indicates that elements of housing design, such as the amount of natural light, adequate ventilation, and pleasant views, can simultaneously contribute to improved mental and physical health (WGBC, 2016). Windows, as the primary daylight source and a visual connection to the outside world, are standard architectural features that have attracted interest from experts in various fields, including architecture, lighting, photobiology, and psychology (Veitch & Galasiu, 2012). This study aims to investigate and analyze the impact of windows on enhancing the mental health of older adults in the Sistan region.

2. Theoretical Framework

2.1 Health concept and its different dimensions in housing

Home is where we live, sleep, and rest; our children have many of their best formative experiences in this space, so we often become emotionally attached to our homes. We spend time and money making houses comfortable, safe, and personal. So, we have a strong connection with our residential buildings, differentiating the house from other types of buildings. (WGBC, 2016). Being healthy is one of the most basic human needs and the basis of human progress and civilization. In Maslow's model of needs, this issue is placed on the first level of the pyramid. The health of societies is created from the health of each family and its members, and housing is the place where the family spends most of its time; housing conditions can have a positive or negative effect on people's health (Salehi, 2010). The World Health Organization is one of the agencies of the United Nations, whose most important goal is to coordinate and improve the public health situation in the world. Based on the definition of this organization, health is defined as the provision of complete physical, mental, and social well-being, which is not limited to the absence of disease and organ defects (Osborn, 1967). According to the World Health Organization (WHO, 2007), it can provide all three dimensions of health, i.e., physical, mental and social health for its residents.

1. Home is the most important space where people spend most of their time.
2. The necessity of society's health is considered the most critical factor in improving the quality of life of individuals and society, the housing of all strata of society and different ages, and if it is unhealthy, it affects a wide range of people.

3. It is necessary to discuss disease prevention in health and hygiene and consider healthy housing as a means to prevent various diseases.

4-Paying attention to health issues in housing and applying its principles and rules will result in economic savings due to the high cost of treatment at the scale of the family, society, and country.

Therefore, housing is an environment with multi-dimensional functions and has different physical, economic, social, financial, psychological and medical dimensions (Cullingworth, 2004). Among them, windows, as providers of daylight and a view to outer space, are standard and have received attention in the specialized fields of architecture, lighting, photobiology, and psychology. Energy and environmental concerns and health and well-being goals have each drawn new attention to the value of windows as a topic of discussion in practical life in these areas (Veitch & Galasiu, 2012).

2.2 Mental health definition

The psychological aspect of health in housing includes all the mental and psychological effects of the physical environment on its residents. Low-quality houses lead to a decrease in the mental health of their residents (Shaw, 2004), and on the other hand, improving the quality of the home environment has a positive effect on improving their mental and psychological health (Thomson & Petticrew, 2005).

2.3 Window's effect on mental health

The Encyclopedia defines a window as "an opening in the wall of a building to obtain light and air." This definition may show a simple diagram of one of the most complex components of a building, while in actual operation, the window has multiple functions. Therefore, it is impossible to agree on the exact role of the window because it has been designed to serve different functions throughout history, and its primary role has changed over time. However, with more emphasis on energy conservation, the window is recovering its multifunctional features by providing daylight and movement for natural ventilation (Kheira & Tabet, 2012). Therefore, windows "in the 20th century are machines that combine several environmental features and should not be considered only as transparent parts of the wall but form a multifunctional element in the home" (WGBC, 2016).

Moreover, beyond these statistics, the house is the permanent residence of a large group of people in society: children, mothers, older adults, disabled people, or people who have limited mobility. Therefore, the quality of the home environment is the most important. The place in our life is worthy of reflection (Gifford, 1987). Quality elements in the environment: The house is a “window” which strongly affects the residents’ emotional, emotional and psychological dimensions (Masoudinejad, 2013).

The window that connects the inside and the outside area fulfils the needs of the residents from the outside area: the need for natural light, the need for fresh air, the need to get information from the outside environment, and the need for a good view, especially in today’s houses. As the window is the only way for the residents to communicate with the outside world and the only house opening to the city, the window has always been considered in terms of urban planning and architecture. Especially in recent decades, the window has been considered one of the most sensitive architectural design elements, and its design principles and criteria have been established (Tahbaz, 2014). Research in the fields related to the effects of health and well-being emphasizes that windows play a significant role in buildings. Empirical research also tells us that daylight through windows lets us see critical physiological functions in daily cycles and promotes positive emotions and alertness. The presence of windows in architectural spaces makes the spaces look pleasant. In addition to providing a tool to discover and perceive the environment, they also help the user’s safety and comfort. The priority of windows is often related to the function of the space and even the resident’s needs. If these variables are not congruent, people will change their space to fit their needs. Therefore, understanding the complexity of human-window interactions is essential in maximizing the fit between living and working spaces and those occupying them (Veitch & Galasiu, 2012).

2.3.1 Natural light

Windows that provide daylight and views of the natural environment are prominent features of the physical environment that promote occupant satisfaction and well-being. Regarding biological factors, the intensity and timing of light exposure can alter circadian rhythms. Body clock synchronization potentially improves peak cognitive performance and work activities in a process known as circadian resetting (Roberts, 2010). By changing circadian rhythms, exposure to light can increase body temperature, lower blood pressure (Badia et al., 1991), and decrease heart rate (Smolders et al., 2012). On an emotional level, people enjoy the feeling of well-being in daylight and sunlight. Prolonged lack of daylight can have psychological effects: for example, at the other end of the spectrum, some people are affected by conditions such as seasonal affective disorder (SAD) during dark winters (WGBC, 2016).

2.3.2 Circadian rhythm

The circadian rhythm (also known as the human body clock) gives people a sense of what time of day it is so that when it is morning, a person is potentially feeling tired but ready to start their day, for the evening is a sense of calmness and a moment that moves downwards. This rhythm is how people live naturally and healthily, and this is why having natural light is essential because windows allow the circadian system to work usually and consistently for humans

(Zanier, 2021). Statistics show that people who spend most of their time in environments with artificial light may be more prone to mood disorders and sleep disorders. Therefore, having windows that bring natural light into our indoor spaces is vital to maintaining health (Boyce, 2003).

2.3.3 Natural ventilation

Natural ventilation can be beneficial because it can bring fresh air from outside into the space while recirculating stale air. Moreover, it is essential because a space's air quality can affect its occupants' health. Although the building code for the window sector focuses more on windows that provide natural ventilation, it is essential to note that having access to fresh air is generally a mandatory rule. Windows help ventilate indoor spaces, reduce the risk of respiratory problems, improve cognitive function, and enhance safety (Zanier, 2021).

2.3.4 Visual vision

Visual vision is an essential and beneficial aspect of windows that allow people to understand life outside the space. This aspect is one of the main components of windows that is hard to argue against, as people want a connection with the outside and a reminder of existing life. The sense of life outside the space in which one is located is essential because it gives one a sense of reality (Farley & Veitch, 2001).

3. Background research

In a research titled Meta-analysis of the factors affecting the mental health of older adults, Arabzadeh examined all the research of quarterly journals and scientific research journals in the field of mental health of senior citizens during the years 2005-2015 and individual, social, psychological and demographic factors are among the indicators (Arabzadeh, 2016). It has been mentioned as effective for older adults. An article called The Biophilic Approach as an Approach to Improving the Quality of the Living Environment of Residents of residential complexes stated that improving the quality of the living environment also means providing appropriate and diverse responses through the environment to the different physiological and psychological needs of the users of that space (Bitraf et al., 2017).

Suppose we want to talk about the evolutionary process of the role of the window in the present era, as it has been discussed since the past. In that case, we can say that one of the effective approaches in recent years is the multi-purpose optimization of the window to provide the user's comfort. In an article titled "The impact of windows, daylight and views of nature on health and well-being in healthcare facilities" Heidi Salonen's team states that the window is one of the most critical factors for designing the physical environment. (Salonen et al., 2014). Today, excellent research has been done on multi-purpose window optimization to provide thermal and visual comfort and energy. Among others, Jiahe Wong, in their study, has provided a multi-purpose framework of thermal and daylight optimization in residential apartments based on window design and natural ventilation, and the results show that natural ventilation is adequate in simultaneously optimizing the goals and improving it (Jiahe et al., 2020). Also, in an article by Mohammadi and Shemirani, the multi-objective optimization of the window shape has been done to simultaneously provide the components of visual comfort and energy efficiency in educational buildings through a genetic algorithm (Mohammadi & Shemirani, 2020). In an article published in 2020, Pilechiha and his colleagues presented a multi-objective optimization framework of daylight, energy, and quality of view in window design of office spaces. Saleh Nasser, in his research, Optimized visibility and light to improve human comfort in the educational process, has been investigated (Saleh, 2021). In an article in 2012 titled “Window design and performance, light, visual comfort, well-being”, Aniseh Khaira refers to the role of windows in the quality of life and well-being, considering the conditions of energy optimization. Yingni Zhaia and his colleagues researched the multi-purpose optimization method for window design, considering energy consumption, ambient temperature, and visual performance (Yingni Zhaia et al. 2018). Most of the conducted researches try to optimize light, reduce energy consumption, and provide thermal comfort in the architectural space, while according to Kevin Steamer, “to truly improve human well-being, building design needs to move beyond the optimal Creating single parameters such as temperature, light and humidity and has a more comprehensive approach that shows its signs in human behaviour (Steemers. k, 2015). Therefore, by reviewing the background of the research, we will reach the point that many studies have been conducted in the field of optimizing and examining the window from the approach of thermal, visual, and climatic comfort, stability, etc., and few studies have investigated the role of the window on mental health.

4. Methodology

Regarding the nature and purpose of this research, it is practical, and its method is based on correlation. The research data was collected in a field study using questionnaires to find the influential factors involved in window design on the mental health of older adults in the Sistan region.

In the first step, the factors involved in window design were extracted from the articles and research, and according to the opinion of architectural experts and experts’ Delphi method, 12 effective indicators in window design were extracted. Then, an analytical matrix was formed, from which a questionnaire with 132 questions was prepared and adjusted. Finally, the scores were analyzed by the arithmetic mean integration method in the SECA analytical matrix system (Tab. 1).

criteria's			Mental health indicators										
			Anxiety	Depression	Sleep quality	Mental and physical security	Stress	Privacy	Communication with outside	Sense of wellness	Cultural and religious beliefs	Physical health	Quietness
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
window Design Criteria	Window Material	A1	2.815	2.815	3.074	3.852	2.963	3.778	2.407	3.259	3.000	3.037	3.778
	Window ratio to wall	A2	3.444	3.630	3.407	3.963	3.185	4.259	4.037	3.852	3.481	3.630	3.889
	Window dimension	A3	3.630	3.556	3.556	4.074	3.481	4.111	4.222	4.000	3.593	3.889	4.111
	Window location	A4	3.444	3.370	3.593	3.889	3.481	4.333	4.111	3.667	3.963	3.333	4.037
	Window direction	A5	3.778	3.815	4.037	4.074	3.778	5.815	3.963	4.148	3.926	3.963	4.185
	Openability	A6	3.519	3.593	3.556	4.037	3.704	4.000	4.296	4.000	3.333	3.741	3.815
	view and scape	A7	3.963	4.074	3.889	4.259	3.741	4.407	4.444	4.296	3.852	4.000	4.185
	Awning	A8	3.111	3.148	3.704	3.741	3.111	3.556	3.593	4.074	3.037	3.630	3.778
	Glass panes	A9	3.259	2.926	3.407	4.111	3.407	3.741	3.519	3.444	3.148	3.444	3.852
	Window form	A10	3.148	2.852	2.704	3.185	2.815	3.074	3.222	3.074	3.222	2.778	3.333
	Glass color and texture	A11	3.741	3.556	3.407	3.852	3.333	4.111	3.852	3.704	3.741	3.148	3.630
	Sill level	A12	3.815	3.815	3.741	3.926	3.667	4.519	4.481	3.667	4.222	3.889	4.148

Tab.1: Analytical matrix and average responses of older adults to the indicators and criteria of the questionnaire

4.1 SECA analytical method

This technique was initially introduced by Mehdi Keshavarz Ghorabaee and his colleagues in 2018. The SECA method represents a novel approach to weighting criteria and ranking options simultaneously, employing a multi-objective nonlinear mathematical model to achieve this objective. To develop the mathematical model, two types of references are defined for the criteria weight. The first type is based on the variation information within the criteria, determined by the standard deviation. In contrast, the second type is linked to the variation information between the criteria, determined based on the degree of correlation. The multi-objective model aims to maximize the overall performance of each option and minimize the deviation of the weight criteria from the reference points. Unlike other methods, the SECA method calculates the decision matrix for weighting the criteria and ranking the options concurrently (Keshavarz Ghorabaee et al., 2018).

4.1.2 Location and time of research

The research's statistical population comprises residential houses in District One of Zabol in the Sistan region, where 80 elderly individuals reside. According to the necessity of determining the sample size, a minimum of 66 individuals were determined through the sample size estimation table of Krejcie and Morgan. To account for potential decreases in respondents, 72 elderly individuals with moderate to high mental health were randomly selected and allocated for participation.

5. Findings

In the current research, data related to the criteria, including factors involved in the window design, denoted as A, and options related to the mental health indicators of older adults, denoted as C, have been collected and presented (Tab. 2).

Following the formation and normalization of the decision matrix, a nonlinear optimization model was constructed and solved using Lingo software. This model was implemented for β values ranging from 0.1 to 7. In each implementation, the criteria weights and option scores were determined. The scores of the options (A) for different values of β are provided in (Tab. 3)

Tab. 2: The creation of the decision matrix

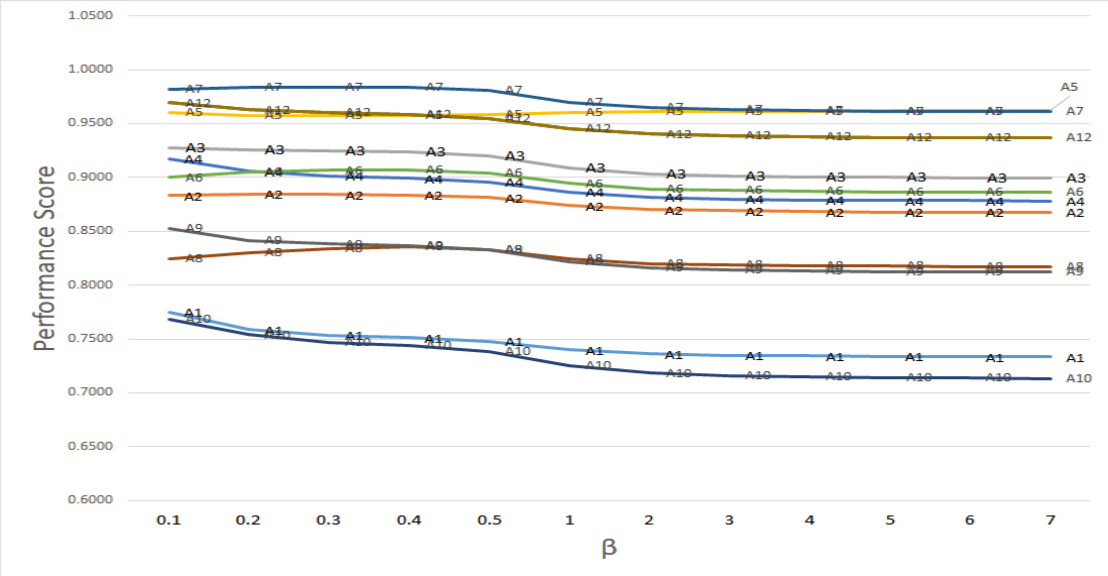
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0.710	0.691	0.761	0.904	0.784	0.650	0.537	0.759	0.711	0.759	0.903
A2	0.869	0.891	0.844	0.930	0.843	0.732	0.901	0.897	0.825	0.907	0.929
A3	0.916	0.873	0.881	0.957	0.922	0.707	0.942	0.931	0.851	0.972	0.982
A4	0.869	0.827	0.890	0.913	0.922	0.745	0.917	0.853	0.939	0.833	0.965
A5	0.953	0.936	1.000	0.957	1.000	1.000	0.884	0.966	0.930	0.991	1.000
A6	0.888	0.882	0.881	0.948	0.980	0.688	0.959	0.931	0.789	0.935	0.912
A7	1.000	1.000	0.963	1.000	0.990	0.758	0.992	1.000	0.912	1.000	1.000
A8	0.785	0.773	0.917	0.878	0.824	0.611	0.802	0.948	0.719	0.907	0.903
A9	0.822	0.718	0.844	0.965	0.902	0.643	0.785	0.802	0.746	0.861	0.920
A10	0.794	0.700	0.670	0.748	0.745	0.529	0.719	0.716	0.763	0.694	0.796
A11	0.944	0.873	0.844	0.904	0.882	0.707	0.860	0.862	0.886	0.787	0.867
A12	0.963	0.936	0.927	0.922	0.971	0.777	1.000	0.853	1.000	0.972	0.991

Tab. 3: Scoring options for different β values

criteria	β											
	0.1	0.2	0.3	0.4	0.5	1	2	3	4	5	6	7
A1	0.7750	0.7588	0.7535	0.7510	0.7479	0.7400	0.7361	0.7348	0.7341	0.7337	0.7335	0.7333
A2	0.8833	0.8846	0.8840	0.8838	0.8813	0.8739	0.8702	0.8690	0.8684	0.8680	0.8677	0.8676
A3	0.9275	0.9258	0.9242	0.9235	0.9198	0.9088	0.9033	0.9015	0.9006	0.9000	0.8996	0.8994
A4	0.9172	0.9055	0.9013	0.8992	0.8957	0.8862	0.8815	0.8799	0.8791	0.8787	0.8783	0.8781
A5	0.9604	0.9574	0.9575	0.9577	0.9583	0.9602	0.9611	0.9614	0.9616	0.9617	0.9618	0.9618
A6	0.8999	0.9054	0.9066	0.9071	0.9041	0.8944	0.8895	0.8879	0.8871	0.8866	0.8863	0.8860
A7	0.9822	0.9840	0.9840	0.9841	0.9806	0.9700	0.9647	0.9629	0.9620	0.9615	0.9612	0.9609
A8	0.8247	0.8298	0.8336	0.8356	0.8332	0.8246	0.8202	0.8188	0.8181	0.8176	0.8174	0.8172
A9	0.8527	0.8417	0.8382	0.8366	0.8326	0.8215	0.8160	0.8142	0.8132	0.8127	0.8123	0.8120
A10	0.7680	0.7538	0.7471	0.7438	0.7387	0.7251	0.7183	0.7160	0.7149	0.7142	0.7137	0.7134
A11	0.8937	0.8838	0.8795	0.8773	0.8735	0.8632	0.8581	0.8563	0.8555	0.8550	0.8546	0.8544
A12	0.9692	0.9627	0.9600	0.9586	0.9550	0.9451	0.9402	0.9385	0.9377	0.9372	0.9369	0.9366

The scores of the options are depicted schematically in (Fig 1). As evident from both the tables and graphs, the graphs converge for values of β greater than 5, exhibiting minimal changes thereafter. Therefore, β=6 can be deemed as the converged value, and the weights of the criteria and the scores of the options are determined at this value, remaining fixed for the problem.

Fig. 1: Weight changes of options for different β values

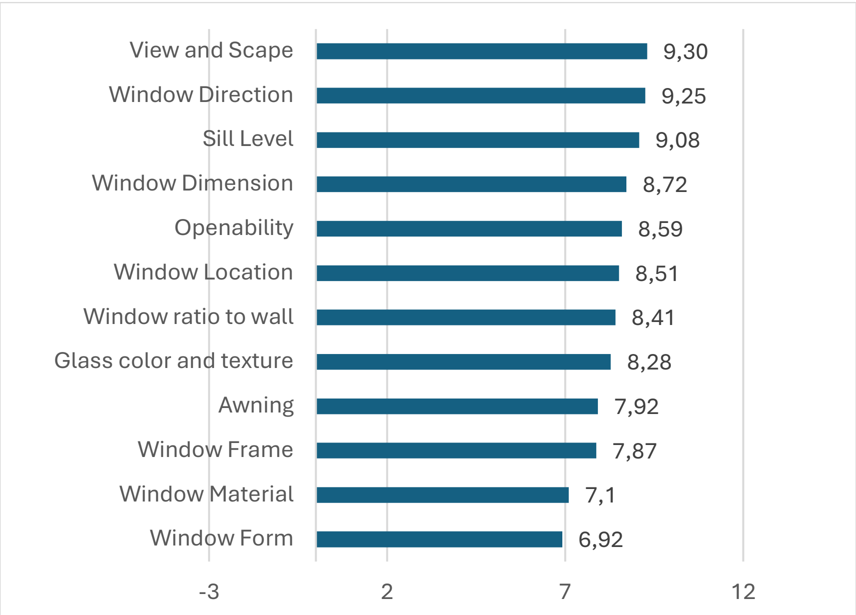


As determined from the results of the Seka method, at β=6, the scores of the options have been calculated and are provided in (Tab.4), respectively. The results are depicted in (Fig. 2).

Tab. 4: Weight and priority of options

Option name	Normalized score (Weight)	Option score	Option code	Rank
Window Material	% 7.10	0.7337	A1	11
Window ratio to wall	% 8.41	0.8680	A2	7
Window dimension	% 8.72	0.9000	A3	4
Window location	% 8.51	0.8787	A4	6
Window direction	% 9.31	0.9617	A5	1
Openability	% 8.59	0.8866	A6	5
View and scape	% 9.31	0.9615	A7	2
Awning	% 7.92	0.8176	A8	9
Glass panes	% 7.87	0.8127	A9	10
Window form	% 6.92	0.7142	A10	12
Glass colour and texture	% 8.28	0.8550	A11	8
Sill level	% 9.08	0.9372	A12	3

Fig. 2: Final score and rank of options



Regarding the options analysis (factors influencing window design), the view and scape were the first, with **9.30% and window** direction the second priority, with 9.29%. Conversely, the window frame, material, and form received the lowest rankings. The analysis indicates a significant relationship between each criterion involved in window design and the mental health of older adults in the Sistan region. Consequently, it can be inferred that the window design can potentially contribute to improving the mental health of the senior citizens in the Sistan region.

6. Conclusion

The increasing elderly population in Iran and globally underscores the significance of addressing elderly health issues. With Iran's elderly population projected to reach 18 million by 1430, according to population forecasts, the identification and prioritization of the psychological and spiritual needs of this demographic, as well as the provision of elderly care services, have become imperative. Since individuals spend a significant portion of their lives at home, the house and residential environment are pivotal in shaping their health and mental well-being. As such, the home environment, often regarded as "the most important place in our life," warrants thorough investigation, particularly considering its profound emotional and psychological impact on residents. Aligning the home environment with the psychological needs of its occupants is paramount.

In light of these findings, prioritizing the factors involved in window design becomes essential for enhancing the mental health of older adults in the Sistan region. Thus, the order of importance from highest to lowest weight ratio should be as follows: view and scape, window direction, window-to-floor distance (sill level), window dimensions, openability, window location, surface-to-window ratio, glass colour and texture, awning, window frame, window material, and window form. In other words, the view and scape emerge as paramount for fostering the mental health of older adults in the Sistan region.

References

Arabzadeh, M. (2016). Meta-analysis of effective factors in the mental health of the elderly. Research in psychological health, 10(2), 42-52. [in Persian]

Badia, P., Myers, B., Boecker, M., Culpepper, J., & Harsh, J. R. (1991). Bright light effects on body temperature, alertness, EEG and behavior. Physiology & Behavior, 50, 583–588.

Boyce, Peter & Hunter, Claudia & Howlett, Owen. (2003). The Benefits of Daylight through Windows. California Energy Commission.

Bitraf, E., Habib, F., & Zabihi, H. (2017), Biophilic attitude is an approach to improving the quality of the living environment of the residents of residential complexes, Urban Management, 49. [in Persian]

Cullingworth, B. (2004). Planning in the USA: Policies, Issues and Processes. New York: Routledge.

Farley, K. M. J. & Veitch, J. A. (2001). A Room with a View: A Review of the Effects of Windows on Work and Well-Being. Institute for Research in Construction, National Research Council Canada, 2001.

Gifford, R. (1987). "Environmental Psychology: principles and practice". Allyn and Bacon. Hanyu, K. (2000). "Visual properties and affective appraisals in residential areas in daylight". Journal of Environmental Psychology, 20 (3): 273–284

Salonen, H., Lahtinen, M., Lappalainen, S., Knibbs, L. D, Morawska, L. & Reijula, K. (2014). The impact of windows, daylight and views of nature on health and well-being in healthcare facilities, The International Sustainable Built Environment Conference windows on work and well-being

Jiahe, W., Masayuki, M., Keiichiro, T., Yanmeng, C., Shigekazu, Y., & Koichiro, S. (2020). Multi-phase framework for optimization of thermal and daylight performance of residential buildings based on the combination of ventilation and window design, Journal of Asian Architecture and Building Engineering

Keshavarz Ghorabaee, M., Amiri, M., Kazimieras Zavadskas, E., Zenonas, T., & Antucheviciene, J. (2018). Simultaneous Evaluation of Criteria and Alternatives (SECA) for Multi-Criteria Decision-Making. INFORMATICA Journal. 29,(2): 265–280. https://doi.org/10.15388/Informatica.2018.167

Kheira, A., & Tabet, A. (2012), windows functions and design: daylighting, visual comfort and well being, Lighting quality and energyefficiency.

Masoudinejad, S. (2013). The sky as a landscape, examining the preference of seeing the sky from the window. Soffe, 23 (3) 27-44. [in Persian]

Mohammadi, F., & Mofidi Shemirani, S. M. (2020). Multi-objective optimization of window shape in order to simultaneously provide visual comfort and energy efficiency components through genetic algorithm (case example: elementary classroom in Tehran, Iran). Geography of the land. 68 (17), 1-20. [in Persian] https://sanad.iau.ir/Journal/sarzamin/Article/823125

Osborn, B.M. (1967). Introduction to Community Health. Boston: Allyn and Bacon Inc.

Roberts, J. E. (2010). Circadian rhythm and human health. Retrieved from http://www.photobi-

ology.info/Roberts-CR.htm.

Sadeghi, R. (2013). The trend of population changes in Iran. Past, present and future, research report, Tehran, Statistical Research and Training center. [in Persian]

Salehi, B. (2010) A look at the Mehr housing program and some architectural and urban planning issues related to it. Abadi, 69. [in Persian]

Smolders, K. C. H. J., Kort, Y. A. W., & Cluitmans, P. J. M. (2012). A higher illuminance induces alertness even during office hours: Findings on subjective measures, task performance and heart rate measures. Physiology & Behavior, 107, 7–16.

Steemers, K. (2015). Architecture for Well-being and Health, Velux Daylight Symposium.

Shaw, M. (2004). Housing and public health, Annual Review of Public Health, 25 (1), 397-418.

Tahbaz, M, (2014), “Pyramid Frame- Shidi Window” Doctoral Dissertation in Architecture, Faculty of Architecture and Urban Planning, Shahid Beheshti University, Tehran. [in Persian]

Thomson, H. & Petticrew, M. (2005). Is HousingImprovement a Potential Health Improvement Straregy? Geneva: WHO Health EvidenceNetwork (Geneva: WHO)

Veitch, J. A., & Galasiu, A. D. (2012). The Physiological and Psychological Effects of Windows, Daylight, and View at Home: Review and Research Agenda.

(WGBC) UK Green Building Council. (2016). The Building Centre.

(WHO) World Health Organization. (2007). World population Ageing, Population Division, and United Nations: New York.

Yingni Zhaia, b., Yi Wanga, C., Yanqiu Huanga, C., & Xiaojing M. (2018), A multi-objective optimization methodology for window design considering energy consumption, thermal environment and visual performance, Renewable Energy, 134, 1190-1199.

Zanier, J. L. (2021). Windows: Beyond Convention Towards Connection, University of Detroit Mercy Dissertation, Thesis.

3 Healthy cities & nature-based living (with care) concepts: **Abstract keynote**

Current challenges of aged research and planning

Luis Salvador-Carulla[1]

[1] Health Research Institute, University of Canberra, Australia

Luis Salvador-Carulla, Professor of Mental Health and Deputy Director of the Health Research Institute at the University of Canberra. Formerly headed the Centre for Mental Health Research at ANU and the Mental Health Policy Unit at the University of Sydney. Specializes in decision support tools for analyzing complex health systems and policy, focusing on mental health, aging, disability, and intellectual developmental disorders. Advised governments of Catalonia and Andalucia, Spanish Ministry of Health, European Commission, and WHO. Coordinated EC projects eDESDE-LTC, Refinement, and PECUNIA, as well as the Integrated Atlas of Mental Health Project, mapping services in 30+ health areas worldwide. Recognized with awards including the Leon Eisenberg Award from Harvard Medical School (2012), Tom Trauer Evaluation and Research Award (2022), Research Impact Award, and Research Excellence Award from the University of Canberra (2023), and the Malaspina Award (2023).

3 Healthy cities & nature-based living (with care) concepts: **Abstract workshop**

A methodology to analyze neighborhoods on living and care using GIS

Otto Trienekens[1], Andrea Fitskie[2]

[1] Veldacademie, The Netherlands

With concepts such as ’10-minute city’ (Buurtstad) and ‘Living & Care circles’ (Woonzorgcirkels), cities as Amsterdam and Brussels are committed to organizing local nodes, where facilities for daily life are within reach for all residents. This focus on local life and neighborhood units touches on several societal questions, for example when it comes to reducing (motorized) transport flows and improving air quality, the viability of small entrepreneurs and equal access to high-quality basic facilities.

The well-functioning of local ecosystems is important for all city residents, but especially for those who are bound to their place of residence and the surrounding area due to aging or some form of physical or mental disability.

Social-spatial research lab Veldacademie (Field Academy) is developing a method to make citywide inventories and analysis of local amenity centers using GIS. The method is mainly quantitative and makes use of public data sources to identify these ‘anchor points’ in the urban fabric.

In order to extent and to interpretate the method with qualitative insights concerning behavior of citizens, and therefore organize a better understanding of the actual need for amenities, we aim to collect more knowledge from various experts on this topic.

In this workshop a brief introduction on the method will be followed by a collective reflection on the question of how to implement qualitative factors into this method. How can the scale of the city (and its urban strategy) be associated with the daily life in neighborhoods? What kind of (invisible) local networks are active, and how do they contribute to informal care? And what are the spatial conditions for community building?

The workshop will be based on the (preliminary) outcomes of studies in the city of Amsterdam. The research, which started in 2015, focuses on living environments for elderly people and is now being extended to care for the mentally and/or physically disabled, homeless and refugees. The results of this complete inventory serves as a basis of knowledge on which the municipal strategic roadmap for housing and care 2024-2034 will be further developed.

4

Smart homes & inclusive communities

4 Smart homes & inclusive communities: **Conference paper**

COOK3R
Designing a smart user-centered cooking aid for enhancing autonomy and nutrition in Dementia Care

Masi Mohammadi[1,2*], Liesbet Rabbinge[1]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

* Corresponding author: Masi Mohammadi (m.mohammadi@tue.nl)

Abstract: Many older people with early-stage dementia continue to live at home, aligned with Dutch care policies advocating for ageing-in-place. This research addresses the critical need for specialized cooking aids for individuals with early-stage dementia living independently, highlighting the development of Cook3r, an AI-based prototype aimed at enhancing nutritional health and autonomy. Utilizing user-centered design methods, including contextual inquiry and home testing, this product is tailored to meet the needs of its users, integrating errorless learning principles to minimize frustration and ensure cognitive compatibility. The importance of empathic technology, developed in collaboration with the target group to improve well-being and quality of life, is emphasized, highlighting the need for ongoing responsiveness to users' (evolving) needs.

Findings suggest that such AI-based technologies can benefit people with mild cognitive impairments by supporting nutritional health, fostering cognitive engagement, and provide a pathway to retain cooking as an enjoyable and fulfilling activity. This not only increases their autonomy but also endorses a comprehensive, user-informed approach in the creation of assistive technologies, aiming to improve the daily lives of individuals with dementia. Advocating for comprehensive, smart support systems, the study promotes a transition towards more holistic approaches in the design of assistive home technologies.

Keywords: Dementia Care, Assistive Cooking Technology, Autonomy, User-Centered Design, Empathic Design

1. Introduction

A significant emphasis is placed on enabling individuals in the early stages of dementia to maintain their independence and continue living at home in the Netherlands. This approach aligns with broader care policies advocating for aging in place, highlighting the critical role of

Activities of Daily Living (ADLs) in preserving autonomy and dignity (Orpwood et al., 2004). Among these activities, cooking stands out as pivotal, yet it presents unique challenges due to the onset of dementia (D'Cunha et al., 2019). The issues of malnutrition, which exacerbate health complications and hasten the progression of the disease, further underscore the urgent need for specialized support in meal preparation to enhance both nutritional health and quality of life (Foloppe et al., 2018).

1.1 Technology acceptance in dementia care

Existing literature on technology acceptance among seniors with dementia highlights that exposure to technology can improve usability perceptions, yet there is no decisive evidence on how it affects broader attitudes towards varied forms of technology. Despite initial resistance and technology anxiety, the increasing actual usage underscores a potential for gradual acceptance (Mohammadi, 2014). However, the overall impact and acceptance remain uncertain and highly variable, reflecting the complex, personalized needs of this demographic. Research indicates that this demographic may exhibit significant resistance to change and technology anxiety, factors that can critically influence technology acceptance (Astell et al., 2010; Morrissey et al., 2016). To address these challenges, an emphasis on user friendliness and intuitive interaction, features that are critical to fostering acceptance among users who are typically cautious about adopting new technologies (Hammink et al., 2023). Such design considerations are pivotal in ensuring that the assistive technology for cooking not only meets the functional needs of individuals with early-stage dementia but also communicates effectively with them, providing necessary cues through both visual and auditory feedback to guide and reassure users during the cooking process.

The acceptance and usability of technology play a crucial role in the development and adoption of assistive solutions for individuals with dementia. Understanding the nuances of technology acceptance among this demographic informs the design and implementation of assistive technologies aimed at addressing specific challenges, such as cooking difficulties.

1.2 Cooking and Dementia

The exploration of cooking activities for individuals with dementia living at home highlights a significant gap in assistive technologies: specific support for cooking, a crucial ADL, is limited. This area requires attention beyond the general focus on care and safety technologies, which, while essential, do not cater to the nuanced needs of cooking (Orpwood et al., 2004). Recent advancements in smart home technologies and Augmented Reality systems show potential in aiding daily living tasks but lack specificity in addressing the cooking needs of individuals with dementia. These technologies often fail to provide the required personalization and adaptability, impacting critical cognitive faculties such as memory, attention, executive functions, and sensory processing. The cARe project by Wolf et al. (2018) explored the use of augmented reality to assist in daily tasks by overlaying visual and auditory cues directly onto the user's environment, indicating a promising avenue for specifically supporting cooking tasks through immersive technology. Similarly, the study by Foloppe et al. (2018) demonstrates the effectiveness of virtual reality in retraining cooking activities for individuals with Alzheimer's through a non-immersive VR kitchen, highlighting the application of errorless

learning and vanishing-cue techniques to facilitate the transfer of skills to real-life settings. This approach underscores the potential of VR to provide targeted support for the cooking needs of individuals with dementia, offering a novel solution to enhance their functional autonomy in the kitchen. Li et al. (2013) introduced a visual surveillance system for the kitchen, utilizing multiple cameras to monitor cooking activities and conditions, offering audio and graphical assistance to users. This system marks a step towards providing adaptive support for seniors with dementia, aiming to facilitate safer and more independent cooking experiences. Manera et al. (2015) developed a serious game for individuals with mild cognitive impairment and Alzheimer's disease, employing a cooking plot to stimulate executive functions and praxis. This innovative approach demonstrates the potential of gamified interventions to provide cognitive support in an engaging and meaningful way, potentially offering valuable insights for the development of interactive cooking aids. Despite the potential of these technologies, ensuring user-friendly and effective solutions

remains a challenge. Evans et al. (2015) emphasize the need for assistive technologies that enhance not just ease of living but also the quality of life, highlighting the importance of devices that support social and recreational activities alongside daily tasks. The "errorless learning" principle is recognized for its efficacy in assisting individuals with early-stage dementia in learning new tasks through clear and straightforward actions. This method leverages the preserved capacity for automatic learning despite episodic memory impairments, promoting a learning process that minimizes errors and enhances daily functioning. The integration of computer-assisted errorless learning technologies has shown to improve cognitive functions significantly (Clare et al., 2000; Dou ZL et al., 2006; Bächle et al., 2018) discuss the unexplored potential of assistive technologies in dementia care, noting structural limitations such as a lack of clinical validation and insufficient focus on the actual needs of individuals with dementia. This points to a gap between the capabilities of technological innovations and their practical application in enhancing the lives of those with dementia. This analysis and examination of existing tools and their integration into the daily lives of individuals with dementia underscore the absence of cooking aids specifically designed for individuals with dementia. It identifies a need for further innovation. Addressing this need involves creating a smart cooking aid that offers personalized, adaptive support, enabling individuals with dementia to engage in cooking activities independently and safely, thus enhancing their autonomy and quality of life at home.

1.3 Cook3r

Recognizing the gap in existing assistive technologies, this paper focuses on the development of the Cook3r—a user centered solution designed to empower individuals with dementia to engage in cooking activities independently and safely (Figure 1). The name, pronounced 'Cooker', is derived from its functionality of simplifying the cooking process into three primary steps: prepare it, cook it, take it. This designation underscores the emphasis on streamlining cooking tasks for individuals with dementia. Despite its advanced features, the Cook3r resembles a conventional induction cooktop, blending seamlessly into the kitchen environment. Developed as a version of a standard induction cooktop brand ATAG, the Cook3r integrates smart technology discreetly. Apart from a screen to support spoken instructions, no other technologies are visible. While these smart features may not be visibly apparent, they play a crucial role in enhancing the cooking experience for individuals with dementia. Grounded in principles of errorless learning (Clare et al., 2000) and user-centered design, this home technology aims to address the specific challenges faced by individuals with dementia in meal preparation. By providing personalized, adaptive support and leveraging AI technology, the Cook3r offers a comprehensive solution that enhances autonomy and quality of life for individuals living with dementia. Utilizing AI to monitor cooking activities in real-time and provide adaptive feedback, the Cook3r aims to enhance safety and reduce cognitive load. It offers guided support for measuring ingredients, maintaining proper cooking temperatures, and providing timely reminders.

Through an exploratory development process, this paper illustrates how the Cook3r has been co-created with users to serve as an assistive device that both supports and stimulates the cooking process.

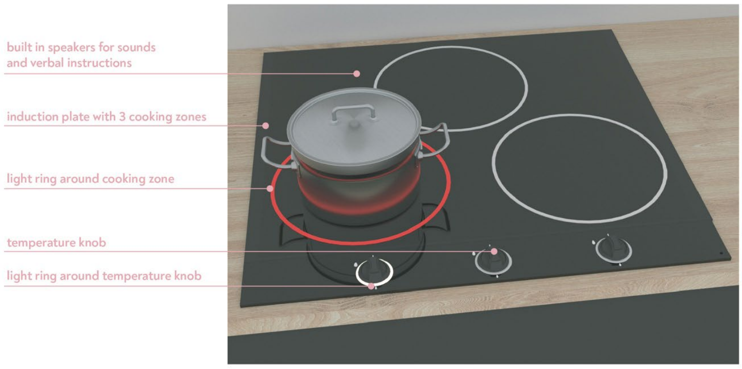


Figure 1. Cook3r to aid in meal preparation aligning with the cognitive capabilities and needs of individuals with early-stage dementia.

2. Methods

The development of the Cook3r, guided by the Empathic Design Methodology, focused on addressing the specific needs, capabilities, and challenges of older individuals with dementia through a user-centered design process (Mohammadi, 2017). This methodical approach included exploration, translation, development, and validation of user interactions to enhance the quality of life for the target demographic.

In the **exploratory phase**, insights were gathered from visits to 5 households aged 62-68 with mild dementia, revealing the daily routines and cooking activities of older individuals with dementia. This phase was enhanced by a literature review on assistive cooking aids and semi-structured interviews with six experts, including case managers, occupational therapists, and a verbal guidance specialist. Data analysis, performed with Atlas TI through open and axial coding, identified key themes.

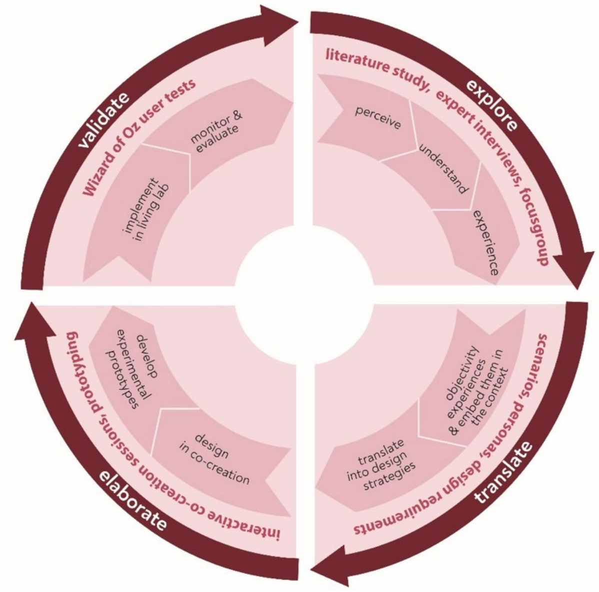


Figure 2. Empathic design methodology (Mohammadi, 2017)

These insights led to the **translation phase**, where personas and scenarios were developed, reflecting the lived experiences of the target group. This step was crucial for grounding the Cook3r prototypes in real-world needs, informed by expert feedback emphasizing usability, safety, and cognitive support. Prototype development was informed by a process phase that distilled cooking-related challenges into actionable design requirements, with feedback loops ensuring alignment with user needs and their capabilities. The final development phase involved two iterative prototype testing within the homes of older individuals with dementia, utilizing the Wizard of Oz method and contextual inquiry for real-time user interaction observation. The Cook3r prototypes were **tested** through two distinct procedures, emphasizing ethical engagement and the role of informal caregivers. In the first scenario, participants were assisted by voice and visual aids from a tablet to prepare a meal, with the setup designed for step-by-step guidance. The second scenario involved participants using the prototype installed on their kitchen stove to cook a meal of their choice, showcasing the prototype's intuitive design for providing assistance through visual and verbal cues. In both testing scenarios, caregivers were asked to remain as observers to encourage independent interaction between the participants and the Cook3r, focusing on identifying interaction signals related to visibility, information transfer, attractiveness, and the effectiveness of the instructions.

This approach not only tested the technical and functional aspects of the prototypes but also placed significant emphasis on ethical considerations and the empathic involvement of caregivers in the research process, ensuring that the development of the cooking aid was deeply aligned with enhancing the autonomy and quality of life of older individuals with dementia.

3. Results and analysis

By detailing the development process and preliminary evaluation of the Cook3r, this analysis, grounded in a combination of empirical research and theoretical insights, contributes to explore the feasibility of enhancing cooking experiences for this demographic. It adheres to the steps outlined in the Empathic Design Methodology, as detailed in the methodology section.

3.1 The exploration phase

The exploration stage involved a comprehensive literature review to ascertain the primary needs and obstacles associated with cooking activities for individuals with dementia. This review uncovered a notable deficiency in existing assistive technologies, which predominantly focus on general safety and care, thus neglecting the specific requirements of cooking tasks. The literature advocates for the concept of 'errorless learning,' highlighting its effectiveness in reducing user errors through intuitive design principles (Clare et al., 2000; Haslam et al., 2006). Participant feedback further underscored the demand for a device that seamlessly integrates into cooking routines without overwhelming the user.

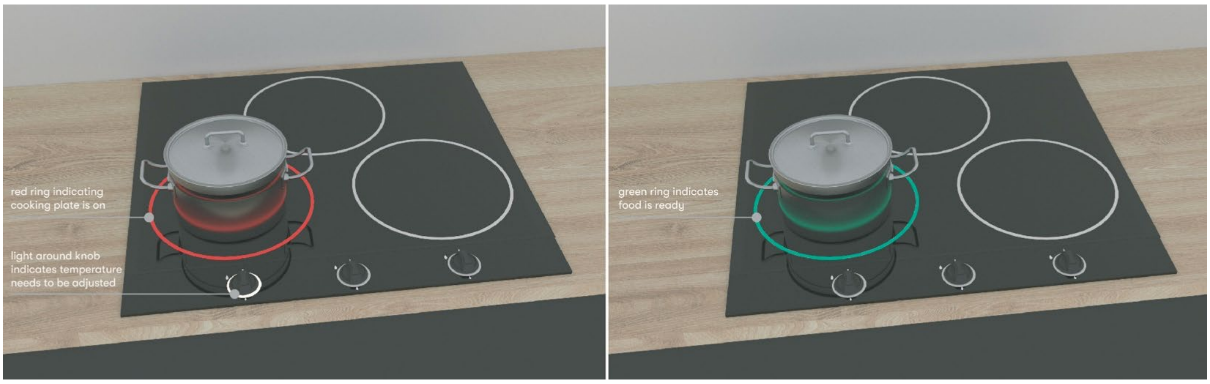


Figure 3. The Cook3r's design emulates conventional cooking appliances to minimize cognitive load while ostering familiarity and ease of use for individuals at various stages of dementia.

3.2. Translating research insights into tangible design

In the process of translating research insights into tangible design specifications for the Cook3r, this study incorporated findings from literature (Köhler et al., 2020; Orpwood et al., 2007; Ancient, C., & Good, A., 2013; D'Cunha et al., 2019) alongside empirical data derived from home visits to individuals with dementia and consultations with experts. The design of the Cook3r aims to emulate conventional cooking appliances to minimize cognitive load while fostering familiarity and ease of use for individuals at various stages of dementia (Astell et al., 2010; Morrissey et al., 2016). Special attention has been given to overcoming hesitation and technology anxiety often observed among older adults with dementia when introduced to new technologies (Astell et al., 2010; Morrissey et al., 2016). To address these challenges, the Cook3r has been designed with an emphasis on user-friendliness and intuitive interaction. User-centered design methods, including contextual inquiry and home testing, aims to ensure that the Cook3r aligns with the cognitive capabilities and preferences of its users, integrating errorless learning principles to minimize user frustration and enhance cognitive compatibility (Clare et al., 2000; Hammink et al., 2023). The design focuses on effective

communication with users through visual and auditory feedback to guide and reassure them during the cooking process. Feedback from users during the cocreation sessions indicates that the device's familiarity makes cooking tasks more manageable and less intimidating.

Enhancements in the Cook3r's design are also influenced by input from (dementia care) experts who alongside literature advocating for the prioritization of auditory instructions to address challenges users face with divided attention. While auditory and verbal instructions are included to cater to individual preferences and allowing for more personalized guidance and support, the application of the modality effect aims to optimize the learning process. Integrating errorless learning principles and user-centered design methods have been employed to ensure that the prototype minimizes user frustration and aligns with the cognitive capabilities and preferences of its users. The application of the modality effect—melding auditory and visual cues—optimizes the learning process by engaging separate channels of working memory, thus facilitating better retention and application of cooking instructions.

The system also incorporates advanced features to accommodate dementia-related challenges such as reduced shortterm memory and delayed response times. It integrates essential error prevention and correction mechanisms, as well as sensors and actuators, to enhance safety and support the cooking process.

Figure 4. Wizard of Oz user testing with Cook3r prototypes (left: the Step-by-Step Cooking Prototype 2021 and right: the Routine-Based Cooking Prototype 2022)

3.3. Development of two prototypes

A thorough analysis of user preferences, capabilities and requirements informed the development of two distinct prototypes: the Step-by-Step Cooking Prototype and the Routine-Based Cooking Prototype. The former offers guided meal preparation through verbal and visual instructions, catering to users with mild dementia who benefit from structured assistance. In contrast, the latter allows for more flexible meal preparation, suiting users with varying dementia stages and personal preferences. User feedback during this phase highlighted improved confidence and enjoyment in cooking, underscoring the prototypes' effectiveness. Central to the Cook3r's design are error prevention mechanisms and the strategic integration of sensors and actuators, intended to offer a responsive and supportive cooking environment. The project emphasizes the significance of engaging users in the development process, advocating for active

participation and collaborative design to ensure that technologies meet the users' lifestyles, capabilities, and needs (Köhler et al., 2020; Moor and Mohammadi, 2019).

3.4. Validation phase

Testing the prototypes in participants' homes yielded critical insights into their practical efficacy. Observations of user interactions and caregiver feedback identified both the prototypes' capacity to positively engage users and pinpointed areas needing refinement, such as instruction recognition and action linkage. This evaluation solidified the Cook3r's design foundation, balancing user autonomy with necessary support. The process of developing the Cook3r underscores the importance of an empathic and user-centric approach, illustrating how such methodologies can inform the development of assistive technologies in dementia care. While the prototype represents a step toward addressing the nuanced needs of individuals with dementia, it also highlights areas for further research and development. As such, the effectiveness of integrating error prevention strategies and adaptive technologies in real-world settings warrants additional investigation.

4. Discussion

In developing cooking aids like the Cook3r for older individuals with dementia, several ethical, technical, and social challenges must be addressed to ensure these technologies are beneficial and widely accepted. Ethically, the balance between enhancing safety through monitoring and preserving the users' privacy and autonomy is paramount. This includes ensuring that informed consent is genuinely understood by individuals with varying degrees of cognitive impairment. It is essential to design systems that monitor and assist without being intrusive, thereby safeguarding users' privacy and autonomy. Additionally, obtaining informed consent presents its own set of challenges, as cognitive impairments may affect an individual's capacity to fully comprehend the implications of using such technologies. Developers must ensure that consent processes are accessible and understandable, engaging caregivers and family members in the decision-making process where appropriate.

Technical challenges include creating adaptable, personalized systems that are intuitive and empathetic. The technology must be capable of learning and adjusting to the unique needs and preferences of each user, providing support that feels natural and unobtrusive. This requires sophisticated algorithms capable of interpreting nuanced user behaviors and preferences, ensuring the device responds in a manner that feels genuinely supportive and understanding. It is crucial to integrate such technology into the users' existing environments without causing disruption or necessitating significant changes to their daily routines. Furthermore, the Cook3r project underlines the significance of these devices being empathic, not just in their functional design, but also in their ability to connect with users on an emotional level, recognizing and responding to the emotional states and needs of individuals with dementia.

Socially, challenges include overcoming the stigma associated with using assistive devices, ensuring (informal) caregiver involvement that supports rather than hinders independence, and addressing the digital divide to make these technologies accessible to all. Addressing these challenges necessitates a cross-disciplinary approach, emphasizing cocreation with users and caregivers, integrating ethical considerations from the outset, and committing to continuous evaluation and improvement. This holistic strategy aims not only to create functional and intuitive cooking aids but also to ensure they are ethically responsible, technically empathic, and socially accepted, ultimately enhancing the autonomy and quality of life for individuals with dementia.

5. Conclusion

Addressing the nuanced requirements of cooking tasks for individuals with dementia living at home, this study contributes to filling a noteworthy gap in assistive technologies. Despite advancements in general care and safety, there has been a notable lack of focus on supports specifically designed for cooking, a critical ADL. The complexity of this ADL activity requires various cognitive skills such as memory, attention, and planning. Expert interviews within this study reveal that diminishing these capacities leads to difficulties in the cooking process, with attention playing a pivotal role. The Cook3r, developed through a user-centered and empathic design process incorporating contextual inquiry and home testing, offers personalized, adaptive support aimed at enhancing the autonomy and quality of life for individuals with dementia who still living at home.

The Cook3r, an AI-based cooking aid, utilizes principles of errorless learning to reduce frustration and guarantee cognitive compatibility, highlighting the critical role of developing technology in close collaboration with the target group. This cooking aid represents an advancement in assistive technology for dementia care, offering a nuanced solution to the challenges of meal preparation. By facilitating the process from initiation to completion of cooking tasks, the Cook3r helps users maintain focus, manage cooking times, and support complex tasks such as using multiple burners. The system will also support decision-making related to mealtimes and meal preparation, and assist in gathering the necessary items and ingredients, although these features are not yet operational but are planned for future development. The potential of this product to support individuals with mild cognitive impairments by aiding in nutritional health, fostering cognitive engagement, and making cooking (again) an enjoyable activity underscores a holistic approach in the development of assistive technologies. A detailed analysis of user needs and preferences informed the development of the Cook3r, ensuring its effectiveness and intuitive use. Incorporating "errorless learning"

and emphasizing user involvement during development, the Cook3r aligns with the cognitive processing styles of its target users. Beyond functional support, it considers users' emotional well-being, aiming to provide a more autonomous and enjoyable cooking experience. As a prototype, the current iteration of Cook3r provides valuable insights into the design of assistive devices that cater to the cognitive and emotional needs of their intended users, paving the way for future advancements in this field. Specifically designed to meet the unique needs of individuals with dementia, the Cook3r aims to enable safe and independent cooking activities. This development addresses specific challenges encountered during cooking and integrates with the users' living culture, significantly enhancing their autonomy and quality of life at home. This product highlights the importance of creating assistive technologies that are functional, intuitive, and in tune with the users' cognitive abilities and daily routines, addressing a significant gap in supportive devices for cooking activities within the dementia care domain. Since cooking is a complex ADL, this study also yields general lessons about supporting individuals with dementia, lessons that could potentially be applied in other domains.

Acknowledgements

We express our gratitude to the seniors with dementia and their caregivers for their active participation in this co-creation project. We also acknowledge the significant contributions of ATAG and all other collaborators whose support was instrumental in the realization of this study. Our thanks to Dr. Ivo Maathuis for his contribution to this research.

References

Bächle, M., Daurer, S., Judt, A., & Mettler, T. (2018). Assistive technology for independent living with

dementia: Stylized facts and research gaps. Health Policy and Technology, 7(1), 98-111. ISSN 2211-8837.

Clare, L., Wilson, B., Carter, G., Breen, K., Gosses, A., & Hodges, J. (2000). Intervening with everyday memory

problems in dementia of Alzheimer type: An errorless learning approach. Journal of Clinical and

Experimental Neuropsychology, 22(1), 132-146. https://doi.org/10.1076/1380-3395(200002)22:1;1-8;FT132

D'Cunha, N. M., Nguyen, D., Naumovski, N., McKune, A. J., Kellett, J., Georgousopoulou, E. N., Frost, J., &

Isbel, S. (2019). A Mini-Review of Virtual Reality-Based Interventions to Promote Well-Being for People Living with Dementia and Mild Cognitive Impairment. Gerontology, 65(4), 430–440. https://doi.org/10.1159/000496905

Dou ZL, Man DW, Ou HN, Zheng JL, Tam SF. Computerized errorless learning-based memory rehabilitation for Chinese patients with brain injury: a preliminary quasi-experimental clinical design study. Brain Inj. 2006

Mar;20(3):219-25. doi: 10.1080/02699050500488215. PMID: 16537263.

Evans, Joanna & Brown, Michael & Coughlan, Tim & Lawson, Glyn & Craven, Michael. (2015). A Systematic Review of Dementia Focused Assistive Technology. Lecture Notes in Computer Science. 9170. 406-417. 10.1007/978-3-319-20916-6_38.

Foloppe, D., Richard, P., Yamaguchi, T., Etcharry-Bouyx, F., & Allain, P. (2018). The potential of virtual reality based training to enhance the functional autonomy of Alzheimer's disease patients in cooking activities: A single case study. Neuropsychological Rehabilitation, 28, 709 - 733. https://doi.org/10.1080/09602011.2015.1094394.

Gitlin, L.N., Winter, L., Dennis, M.P., Corcoran, M., Schinfeld, S., & Hauck, W.W. (2003). "A randomized trial of a multicomponent home intervention to reduce functional difficulties in older adults." Journal of the American Geriatrics Society, 51(5), 657-664.

Keller, H. H., Beck, A. M., & Namasivayam, A. (2015). "Malnutrition in institutionalized elderly people with dementia: the role of dietary intake and eating behavior." Journal of Nutrition, Health & Aging, 19(10), 1029-1037.

Hammink, J. H. W., Moor, N., & Mohammadi, M. (2023). Influencing Health Behaviour using Smart Building Interventions for People with Dementia and Mild Cognitive Impairment: Expert Interviews and a Systematic Literature Review. Disability and Rehabilitation: Assistive Technology, 18(7), 1175-1191. https://doi.org/10.1080/17483107.2021.1994032

Köhler, S., Görß, D., Kowe, A., Kirste, T., & Teipel, S. (2020). Use-cases and users´ requirements for design of an individualized sensor-based assistive system for people with dementia in nursing facilities- A user centered design approach using qualitative research. Alzheimer's Association International Conference.

Lee, G. Y., Yip, C., Yu, E. C. S., & Man, D. (2013). Evaluation of a computer-assisted errorless learning-based memory training program for patients with early Alzheimer’s disease in Hong Kong: a pilot study. Clinical Interventions in Aging, 8, 623-633. DOI: 10.2147/CIA.S45726

Li, Y., Asghar, M. Z., & Pulii, P. (2013). Visually-aided smart kitchen environment for senior citizens suffering from dementia. In *2013 International Joint Conference on Awareness Science and Technology & Ubi-Media Computing (iCAST 2013 & UMEDIA 2013)* (pp. 584-590). Aizu-Wakamatsu, Japan: IEEE. https://doi.org/10.1109/ICAwST.2013.6765507

Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., Brayne, C., Burns, A., Cohen-Mansfield, J., Cooper, C., Costafreda, S.G., Dias, A., Fox, N., Gitlin, L.N., Howard, R., Kales, H.C., Kivimäki, M., Larson, E.B., Ogunniyi, A., Orgeta, V., Ritchie, K., Rockwood, K., Sampson, E.L., Samus, Q., Schneider, L.S., Selbæk, G., Teri, L., & Mukadam, N. (2020). "Dementia prevention, intervention, and care: 2020 report of the Lancet Commission." The Lancet, 396(10248), 413-446.

Manera V, Petit PD, Derreumaux A, Orvieto I, Romagnoli M, Lyttle G, David R, Robert PH. 'Kitchen and cooking,' a serious game for mild cognitive impairment and Alzheimer's disease: a pilot study. Front Aging Neurosci. 2015 Mar 17;7:24. doi: 10.3389/fnagi.2015.00024. PMID: 25852542; PMCID: PMC4362400.

Mohammadi, M. (2017). Empathische woonomgeving. Technische Universiteit Eindhoven.

Mohammadi, M. (2014). Domoticakompas: Inzichten uit een decennium slimme zorgprojecten in

Nederland. Eindhoven: Van Litsenburg Beheer, Printing company: Scholma Druk B.V. ISBN: 978-90-902830-0-5

Moor, N., & Mohammadi, M.M. (2019). Grey Smart Societies: Supporting the Social Inclusion of Older Adults by Smart Spatial Design. Data-driven Multivalence in the Built Environment.

Orpwood, Roger & Chadd, J. & Howcroft, Debra & Sixsmith, Andrew & Torrington, Judith & Gibson, Grant & Chalfont, Garuth. (2010). Designing technology to improve quality of life for people with dementia: User-led approaches. Universal Access in the Information Society. 9. 249-259. 10.1007/s10209-009-0172-1.

Van der Roest, H.G., Meiland, F.J.M., Comijs, H.C., Derksen, E., Jansen, A.P.D., Van Hout, H.P.J., Jonker, C., Dröes, R.M. (2009). "What do community-dwelling people with dementia need? A survey of those who are known to care and welfare services." International Psychogeriatrics, 21(5), 949-965.

Wolf, D., Besserer, D., Sejunaite, K., Riepe, M., & Rukzio, E. (2018). cARe: An Augmented Reality Support System for Dementia Patients. Adjunct Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology. https://doi.org/10.1145/3266037.3266095.

World Health Organization. (2015). World Report on Ageing

4 Smart homes & inclusive communities: **Conference paper**

Clinical Decision Support Strategy for Enhanced BPSD Management with LLMs
Enhancing BPSD Management via Conversational AI: Leveraging Decision Support

Parsa Safaee[1*], Niloufar Sheykhi[2*], Hugo Hu[1]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] The University of Sheffield, England

*Corresponding author: Parsa Safaee (Safaee.pa@gmail.com)

Abstract: The escalating global prevalence of dementia, particularly in the aging population of the Netherlands, presents significant challenges in managing Behavioral and Psychological Symptoms of Dementia (BPSD). These challenges necessitate innovative AI-enabled approaches to enhance the quality of care and support for affected individuals and their caregivers. In this paper examined how Clinical Decision Support Systems (CDSS) can be incorporated into conversational AI to enhance the management of Behavioral and Psychological Symptoms of Dementia (BPSD). Leveraging the capabilities of Large Language Models (LLMs) and adopting a decision-support approach utilizing Retrieval-Augmented Generation (RAG) frameworks. The study underscores the critical role of AI chatbots in non-pharmacological interventions and advanced decision-support technologies in dementia care. By combining decision-making frameworks such as game theory, decision trees, and the maximin strategy with LLMs, conversational AI can offer tailored, responsive interactions that improve therapeutic outcomes. This integration promises to transform dementia care by providing personalized support and mitigating the limitations of current AI technologies, such as "hallucinations" and unclear processes of decision-making in LLMs. This research identifies a gap in the literature concerning decision support for AI interactions in dementia care and proposes an innovative framework for implementing decision-support systems to address this challenge. The findings suggest that smart, conversational AI applications incorporating Clinical decision support systems (CDSS) can significantly enhance the management of BPSD, offering a strategic and user-centered approach in a healthcare ecosystem increasingly reliant on responsible, human-centered technology.

Keywords: Virtual-Caregiving; Dementia-Care; Decision-Support Strategy, AI-chatbots, LLMs

1. Introduction

1.1 Dementia as a Global Concern:

Dementia is a worldwide health concern characterized by cognitive decline, impacting daily functioning and interpersonal relationships. It encompasses various diseases, such as Alzheimer's, and is marked by abnormal brain changes (Alzheimer's Association, 2024; Gatchel, 2020).

Dementia affects approximately 46 million individuals worldwide, a number projected to increase to 131.5 million by 2050 (Prince et al., 2015). In the Netherlands, approximately 260,000 individuals are currently living with dementia. This figure is projected to reach 400,000 by 2050, driven by a growing senior population and an increasing average age (Ministerie van Volksgezondheid, Welzijn en Sport, 2017).

1.2 Dementia Symptoms:

Most individuals with dementia experience behavioral and psychological symptoms (BPSD), which are seen as a consequence of dementia's cognitive decline and advancement (Canevelli et al., 2013), underscoring the pivotal role of caregivers on the frontline in managing these symptoms. Among these symptoms, emotional disturbances, aggression, depression, and isolation, affect up to 97% of community-dwelling individuals with dementia, significantly impacting their quality of life and posing challenges for caregivers (Cloak, 2022; Baharudin et al., 2019; Feast et al., 2016).

Symptoms that lead to functional impairment and caregiver burden often appear long before diagnosis, underscoring the importance of early detection and intervention (Basu & Mukhopadhyay, 2022).

1.3 Caregiver Support for Dementia Care:

The access to Caregiver Support Ratio (CSR) is projected to decrease by 55% in Europe, and from 2020 to 2050, the challenges of managing dementia are further underscored (Ribeiro et al., 2021b, Table 1). This trend is even more pronounced in the Netherlands, where a 62.3% decrease in CSR is anticipated, significantly impacting dementia care service (Ribeiro et al., 2021b, Table 1).

BPSD may also provoke pressure on caregivers, causing distress and burden (Feast et al., 2016) and potentially resulting in hospital admissions or emergency room visits for people with dementia (Nourhashémi et al., 2001; Toot et al., 2016; Yaffe et al., 2002).

BPSD management, centered on caregivers, significantly impacts care costs, accounting for over 25% of indirect and 35% of direct annual expenses for community-dwelling individuals with Alzheimer's (Beeri et al., 2002). The varied origins of BPSD mean no "one size fits all'' treatment exists (Kales et al., 2020). AI interventions have great potential to optimize and support automation of personalized care for people with dementia, addressing the challenge of people with dementia and their caregivers (Hird et al., 2023). The shortage of trained caregivers and difficulties in consistently implementing psychosocial interventions have led to increased interest in digital technologies (Moyle, 2019; Astell et al., 2019). This trend has been accelerated by the COVID-19 pandemic (Barbosa et al., 2023).

1.4 Non-Pharmacological Dementia Care:

Psychiatric medications aim to reduce BPSD despite lacking FDA approval, limited evidence of benefits, and significant associated risks, including mortality (Maust et al., 2015). Nonpharmacologic treatments, unlike medications, offer significant benefits to individuals with dementia and their caregivers (Kales et al., 2015; Brodaty & Arasaratnam, 2012). Due to the negative side effects of psychotropic medications used for BPSD, non-pharmacological approaches were proposed as the primary treatment (Oliveira et al., 2015). It was recognized that non-pharmacological therapies might successfully manage BPSD costs (Park et al., 2019; Cai et al., 2020) and lower BPSD side effects more effectively (Burley et al., 2020). The DICE Approach is a validated common non-pharmacological method for addressing BPSD, encompassing Describing, Investigating, Creating, and Evaluating techniques (Kales et al., 2014, 2020). Within this framework, modifications are employed to alleviate symptoms such as agitation and aggression. This structured approach enhances support and quality of life for individuals with dementia and their caregivers (Kales et al., 2020). In our research, we will incorporate the conceptual framework of DICE Approach, acknowledging its importance in user-centered care. LLMs have recently been used in therapeutic conversations for individuals with dementia, offering adaptation and personalization (Xygkou, 2024), suggesting potential for implementing the DICE framework to manage BPSD.

Figure 1. DICE BPSD Management Framework Process

1.5 Therapeutic AI in Healthcare:

In practice, technology enhances and supplements skills, and effective integration determines the overall outcome (Tschang & Almirall, 2021). The increasing use of digital health technologies, driven by rising demand for home care and caregivers worldwide, reflects a shift in public healthcare systems (Hallqvist, 2021; Coughlin, 2006). Families and caregivers can benefit from various digital support systems such as mental health resources, safety measures, and virtual caregiving options (Blazer et al., 2016). Smart technology has been identified as essential for improving the living environment for aging groups in their homes, enhancing physical and mental independence, security, and comfort (Chabot et al., 2019; Labonnote & Høyland, 2017; Morris et al., 2014; Ma et al., 2021). This trend towards home care for people with dementia has spurred exploration into AI applications for supporting people with dementia, yet an overview of opportunities and challenges remains lacking (Qi et al., 2022).

Artificial Intelligence (AI) technologies, integrated into routine tasks, drive broader automation, and revolutionize industries through streamlining tasks and enhancing decision-making (Tschang & Almirall, 2021; Topol, 2019b; Huddle et al., 2023). Implementing scalable AI systems, platforms, and applications shows promise in efficiently addressing healthcare challenges (Hallqvist, 2021). Research indicates AI-enabled mental health interventions are as effective as traditional in-person treatment in reducing anxiety and depression (Linardon et al., 2019; Carlbring et al., 2017; Leo et al., 2022). Additionally, AI technology can be widely utilized for diagnosing and classifying cognitive issues through models trained on big data (Graham et al., 2019).

1.6 Enhancing Mental Health Support with Conversational AI - Opportunities and Challenges:

In mental health support applications, structured dialogue systems are crucial for counseling strategies (Izumi et al., 2024). Leveraging advanced deep learning methods like neural networks and training on extensive datasets from various sources, LLMs mimic human language comprehension abilities, producing highly logical and lifelike results (Cascella et al., 2023). Despite the need for thoughtful responses, integrating LLMs to generate context-sensitive replies can significantly enhance these applications (Izumi et al., 2024).

Conversational AI applications, often embodied by LLMs, adeptly lead users through therapeutic conversations, targeting concerns such as desperation and anxiety. They focus on improving symptoms particularly among regular users (Leo et al., 2022b; Inkster et al., 2018). Within these applications, therapeutic dialogues effectively address mental health issues and mitigate distress (Sarker, 2022b). These capabilities cover recognizing, adapting, reasoning, understanding, absorbing abstract ideas, and responding to specific human traits such as creativity, emotion, and attention (Korteling et al., 2021).

Mental health-improving apps heavily incorporate dialogue systems controlled by pre-established or rule-based scenarios developed from treatment methods. These systems are further enhanced by employing recently developed LLMs to generate contextually relevant utterances, though with the need for responsible responses (Izumi et al., 2024). However, LLMs exhibit impressive abilities but struggle with inaccuracies, including 'hallucinations,' outdated information, and non-transparent processes (Gao et al., 2023).

The occasional lack of complete reliability in AI systems fosters mistrust and fear, hindering the development of new applications, especially in critical scenarios where mistakes could cost at the expense of human life (Nicodème, 2020). Risks associated with LLMs, especially hallucinations when handling queries outside their training data or requiring current information, highlight the need for caution when using them as a black-box solution (Zhang et al., 2023; Gao et al., 2023).

To address these challenges, Retrieval-Augmented Generation (RAG), introduced by Lewis et al. (2020), enhances LLMs by incorporating external databases, thereby boosting accuracy and reliability for tasks requiring deep knowledge. By querying relevant information from external sources before text generation, RAG ensures outputs are grounded in evidence, offering significant improvements in precision and relevance (Wang et al., 2023; Gao et al., 2023). Access to external information can facilitate knowledge formulation in LLMs (Pouplin et al., 2024) making them integral in contemporary healthcare alongside Clinical Decision Support Systems (CDSS) (Levick et al., 2012; Ong et al., 2024).

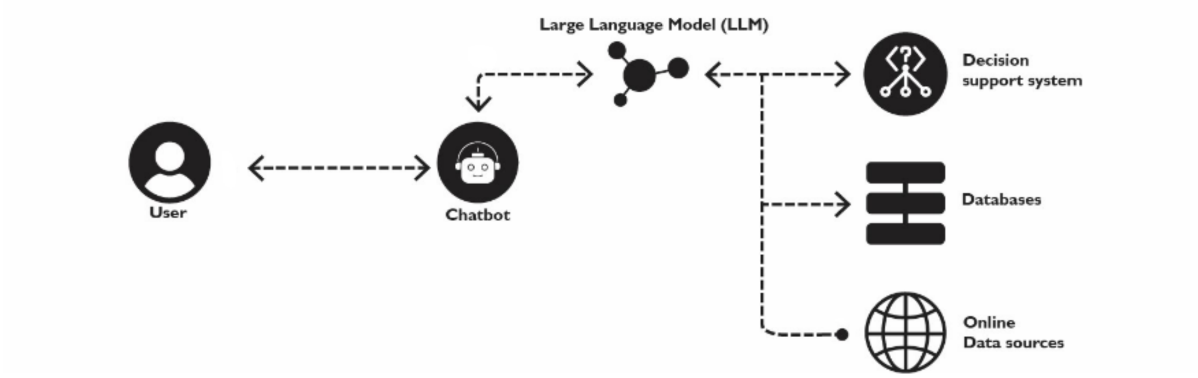


Figure 2. Integrated decision support through RAG within LLM - Conversational AI chatbot for BPSD management

In healthcare, the integration of AI, particularly CDSS, holds significant potential to enhance decision-making processes (Bleher & Braun, 2022; Lysaght et al., 2019). However, ethical concerns, including bias, privacy, and their impact on therapeutic relationships, must be carefully considered (Martinez-Martin, 2021). Strategies to mitigate AI's drawbacks while maximizing its benefits are crucial for optimizing AI systems (Raisch & Krakowski, 2020). Addressing common decision support strategies widely used in healthcare can profoundly benefit generative AI applications by supporting various functions.

1.7 Decision Support frameworks for Therapeutic Conversational AI:

CDSS utilizes a range of frameworks and techniques such as rule-based systems, fuzzy logic, artificial neural networks, Bayesian networks, and machine learning algorithms (Wagholikar et al., 2012). Integration of Generative AI and Decision Support System (DSS) presents an array of health monitoring capabilities within Ambient Assisted Living (AAL) environments (Billis et al., 2015). This study concentrates on combining three well-known decision-making strategies in healthcare into a conceptual framework for decision support, particularly focusing on managing BPSD in individuals with dementia. These chosen frameworks are selected for their capacity to handle the intricacies of decision-making while ensuring clarity in managing BPSD using LLMs. Although other methods are available, this research aims to evaluate the suitability of these three strategies for RAG systems and wider applications, recognizing that effective automated decision-making strategies may encompass more than those discussed.

Table 1. Decision Support Frameworks Applications for BPSD Management through LLMs.

Decision-Making Strategy	Area of Application
Game Theory	Strategic Interactions
Decision Tree	Structured Analysis
Maximin	Risk-Control

1.7.1 Game Theory

Game theory, a mathematical framework widely used in healthcare, predicts strategic behavior where players' decisions directly impact outcomes (Blake & Carroll, 2016). In dementia care, individuals with dementia and AI caregivers act as players, influencing therapeutic interventions. Strategic conflicts can be modeled in simplified "games" with rational players making decisions based on each other's strategy (Blake & Carroll, 2016; Dixit, 2005). Care providers face situations where they must balance individual reasons with the greater good, prioritizing societal welfare over personal interest in their duties (Blake & Carroll, 2016). While no model perfectly captures human personalities, game theory analyzes interdependent strategic behavior in healthcare scenarios (Blake & Carroll, 2016). This approach enables the AI to analyze interventions for BPSD management, comprehend the dynamics of decision-making, and identify optimal strategies to enhance individual well-being while minimizing adverse effects.

1.7.2 Decision Trees

Decision trees streamline decision-making by considering multiple factors sequentially, improving efficiency (DeSanctis & Gallupe, 1987). Integrating them into clinical psychology chatbots revolutionizes mental health support, offering tailored interventions for well-being (Bendig et al., 2019). Their fusion with LLMs enhances decision-making across medical fields (Miao et al., 2024), while in virtual healthcare, decision trees incorporating physiological factors enable efficient automated diagnostic services (Hua et al., 2019; Azar & El-Metwally, 2012).
Decision trees are utilized by conversational AI (Kulkarni et al., 2019); providing individualized options for treatment based on variables such as symptoms, medical history, and past intervention reactions (Rosas et al., 2019; Kulkarni et al., 2019). This makes it possible to provide personalized advice for every user (Shumanov & Johnson, 2021). This highlights decision trees' effectiveness in offering a systematic approach to evaluating BPSD management, navigating complex issues in each stage, and promoting comfort.

1.7.3. Maximin

The maximin principle, used in decision-making under uncertainty, aims to maximize the minimum outcome to protect the most vulnerable, focusing on minimizing risks (Fried, 2020). It serves as a structured decision-making rule (Harsanyi, 1975) and is particularly valuable in healthcare, where it emphasizes safety by preparing for the worst-case scenarios (Brody & Thompson, 1981). In such contexts, it prompts immediate human intervention in critical situations, such as when conversational AI detects urgency in interactions with people with dementia, effectively minimizing harm.

2. Methods

This literature review examines scholarly research on integrating conceptual decision support frameworks into Conversational AI within dementia psychological healthcare, particularly focusing on addressing Behavioral and Psychological Symptoms of Dementia (BPSD) management. After a careful screening process, 79 papers were selected from the initial selection of 217 articles identified via keyword searches on Google Scholar, WorldCat Library, ResearchGate, and PubMed. The discovery of relevant papers on these platforms requires comprehensive keyword searches. Reviewing and back-and-forth searching article citations to obtain varied articles and papers improves our understanding of the area and identifies knowledge gaps. The study used ChatGPT-4 to find knowledge gaps in relevant publications and suggest relevant articles, increasing research integrity and methods. Peer-reviewed publications, meta-analyses, systematic reviews, literature reviews, technical papers, and tool papers were selected using strict inclusion criteria, preferring recent materials from the last decade while considering earlier references for historical context or foundational knowledge. This comprehensive literature review strategy ensured a thorough examination of current research across relevant disciplines, laying a solid foundation for the investigation, drawing from IEEE, International Journal of Psychiatry, NCBI, and arXiv.

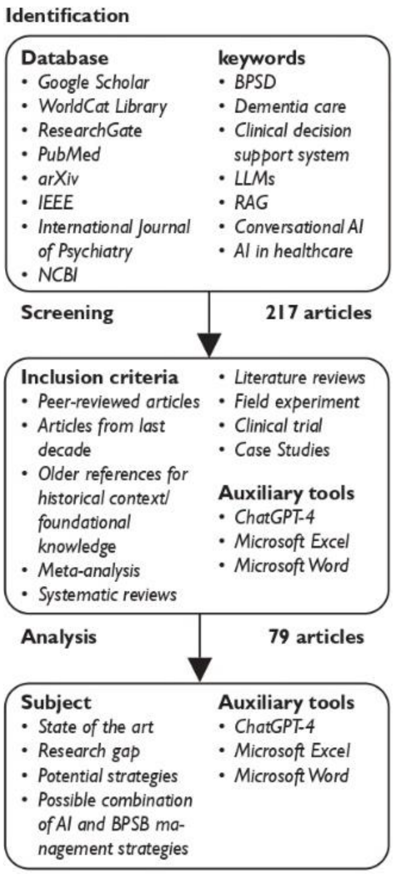


Figure 3. Research methodology diagram

3. Results and analysis

After conducting a comprehensive literature review, utilizing backward and forward research methodologies across various platforms and leveraging tools like ChatGPT-4 and back and forth search for citations, it became evident that while there is considerable discussion on the automation and utilization of AI within the healthcare sector (Bleher & Braun, 2022; Lysaght et al., 2019) specifically dementia sector, there remains a scarcity of resources specifically addressing the integration of decision support strategies within Large Language Models (LLMs) in the realm of dementia care, particularly in clinical decision support systems (CDSS) for managing Behavioral and Psychological Symptoms of Dementia (BPSD). While LLMs demonstrate promising potential, occasional inaccuracies in their outputs (Zhang et al., 2023; Gao et al., 2023) emphasize the need for refinement, particularly within healthcare contexts.

To address this gap, this paper proposes a conceptual framework, as shown in Figure 3, aimed at enhancing the accuracy of decision-making in BPSD management (Levick et al., 2012; Ong et al., 2024) through the integration of LLMs into various decision support frameworks such as game theory (Blake & Carroll, 2016), decision trees (Kulkarni et al., 2019), and maximin (Brody & Thompson, 1981) in complementing framework. Through integration with LLMs via RAG (Wang et al., 2023; Gao et al., 2023), this framework harnesses each of these approaches to optimize the implementation of automated clinical decision support in various BPSD management scenarios through AI-powered therapeutic interactions with individuals affected by dementia.

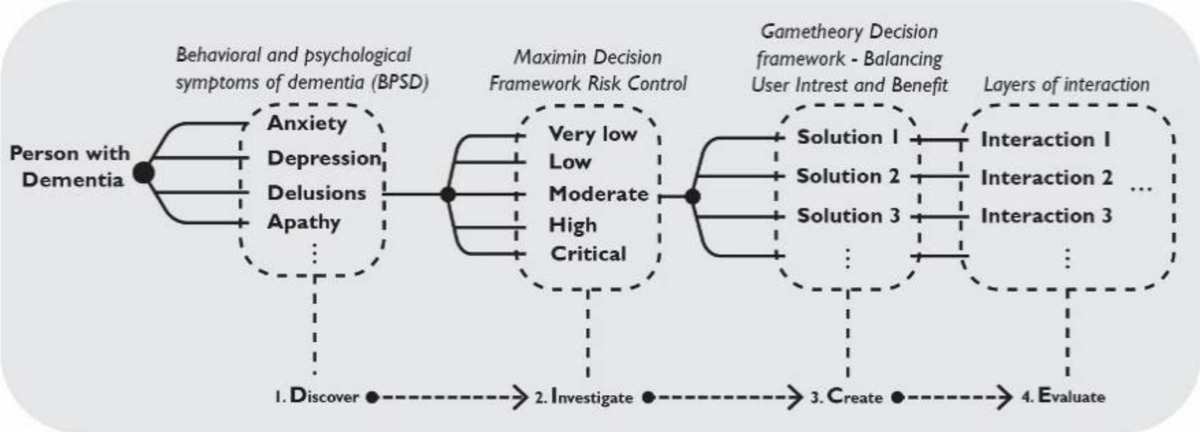


Figure 4. integrated Clinical Decision Support Strategy through RAG within LLM - Conversational AI chatbot for BPSD management

By employing game theory, the framework effectively balances the diverse interests of individuals with dementia and the AI system, optimizing therapeutic dialogues for improved patient outcomes. The decision tree component organizes complex decision-making processes, guiding the CDSS through logical

sequences of therapeutic interventions based on real-time user data and historical information. This structured approach notably enhances decision accuracy, leading to increased user engagement and reported satisfaction during our evaluations.

Additionally, utilizing the maximin strategy enables the framework to anticipate and mitigate risks and emergencies, further highlighting its preemptive capabilities. This strategy prioritizes the minimization of potential adverse effects, ensuring safer therapeutic interactions for dementia patients.

The proposed integration of enhanced LLMs into the CDSS, illustrated in Figure 3, represents a significant advancement in BPSD management, showcasing the profound impact of the integration clinical decision support framework in Conversational AI for healthcare. The positive outcomes observed in this study underscore the potential of this framework to revolutionize dementia care, warranting further exploration into its broader application and scalability.

4. Discussion

This conceptual method uses external datasets along with Retrieval Augmentation Generation (RAG) and Decision Support for BPSD management; hence, data availability is crucial. Numerous data providers and data augmentation techniques address healthcare, but their value depends on data specificity and relevance. Incorporating data augmentation techniques for text grouping in BPSD holds promise for enhancing conversational AI in BPSD management (Kosugi et al., 2021). Healthcare leaders can exchange information to improve BPSD decision support systems and AI chatbots. Such collective efforts aim to build a robust foundation for advanced AI development, significantly boosting healthcare services. LLM research in healthcare demonstrates promise and limitations, with persistent gaps in evaluation, applicability, and evidence (Park et al., 2024), alongside the risk of generating inaccurate "hallucinations" (Ouyang et al., 2022). Although RAG (Reality Augmentation Glasses) can decrease and alleviate hallucinations, it cannot completely terminate hallucination occurrence possibility (Dong,2024). Standardized evaluation methods such as ROUGE, METEOR, and G-Eval assess LLM applications, ensuring effectiveness and safety for users (Park et al., 2024); however, there is a need for specific evaluation methods and frameworks tailored to chatbots and LLMs applications to ensure their effectiveness and safety. In healthcare applications, due to the high-risk nature of the domain, human-in-the-loop systems are necessary for developing and validating LLMs for high-stakes tasks, while low-stakes tasks may be automated with appropriate safeguards (Ahmad et al., 2023). Automated LLM hallucination evaluation solutions, such as Nvidia's NeMo Guardrails, advance alongside ongoing standardization efforts, ensuring efficient and reliable assessment methods (Ding et al., 2024). Finally, assessment and compliance assurance throughout the lifecycle of an LLM application are crucial for risk detection, continuous improvements through feedback loops, and the advancement of responsible AI practices.

5. Conclusion

In conclusion, the escalating global dementia crisis necessitates innovative and effective management strategies to address the complex challenges faced by individuals with dementia and their caregivers. This review highlights the paramount importance of nonpharmacological interventions and the transformative potential of integrating conversational AI and clinical decision support systems (CDSS) in dementia care. By leveraging advanced technologies such as Large Language Models (LLMs) and Retrieval-Augmented Generation (RAG), alongside decision-making frameworks like game theory, decision trees, and the maximin strategy, conversational AI can significantly enhance personalized support and therapeutic interventions. These technological advancements promise to improve the quality of care and support for individuals with dementia and their caregivers, offering a strategic and patient-centered approach to managing the behavioral and psychological symptoms of dementia (BPSD). The integration of smart care conversational applications in dementia care represents a critical step towards a responsible AI in the healthcare ecosystem that prioritizes human-centered technology and sophisticated decision-making capabilities, marking a significant advancement in addressing the dementia and BPSD challenges.

Acknowledgements

We give our genuine gratitude to the people who supported us throughout the development of this research, Dr. Yousef Nejatbakhsh, Assistant Professor at Caldwell University, and Dr. Olivia Guerra Santin, Assistant Professor at Eindhoven University, supported this research with their invaluable feedback and insights. Furthermore, we would like to extend our gratitude for the assistance provided by Dr. Malihe Aliasgari, Assistant Professor at Kean University. Her profound insight and counsel played a pivotal role in advancing our understanding and improving our research theorical foundation.

References

Alzheimer's Association. (2024). What is dementia? Alzheimer's Disease and Dementia. https://www.alz.org/alzheimers-dementia/what-is-dementia

Gatchel, J. R. (2020). Late-Life Neuropsychiatric symptoms: windows into cognitive decline? The American Journal of Geriatric Psychiatry, 28(1), 72–74. https://doi.org/10.1016/j.jagp.2019.08.017

Prince, M., Wimo, A., Guerchet, M., Ali, G., Wu, Y., & Prina, M. (2015). World Alzheimer Report 2015.The Global Impact of Dementia: An analysis of prevalence, incidence, cost and trends. In HAL (Le Centre Pour La Communication Scientifique Directe). https://hal-unilim.archives-ouvertes.fr/hal-03495438

Ministry of Health, wellbeing and sports of Netherlands. (2017, May 17). Working together internationally to tackle dementia. Government.nl. Retrieved August 25, 2023, from https://www.government.nl/latest/news/2017/05/16/working-together-internationally-to-tackle-dementia#:~:text=Challenges%20for%20the%20Netherlands&text=In%20the%20Netherlands%2C%20an%20estimated,age%20will%20become%20progressively%20higher

Canevelli, M., Adali, N., Cantet, C., Andrieu, S., Bruno, G., Cesari, M., & Vellas, B. (2013). Impact of behavioral subsyndromes on cognitive decline in Alzheimer's disease: data from the ICTUS study. Journal of Neurology, 260(7), 1859–1865. https://doi.org/10.1007/s00415-013-6893-3

Cloak, N. (2022, July 21). Behavioral and psychological symptoms in dementia. StatPearls - NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK551552

BaharudinAD,Din NC,Subramaniam P,Razali R.The associations between behavioral-psychological symptoms of dementia (BPSD) and coping strategy, burden of care and personality style among low-income caregivers of patients with dementia. BMC Public Health. 2019 Jun 13;19(Suppl 4):447. doi: 10.1186/s12889-019-6868-0. PMID: 31196141; PMCID: PMC6565534.

Basu, I., & Mukhopadhyay, S. (2022). Neuropsychiatric symptoms of dementia and caregivers' burden: a study among Indian caregivers. Dementia & Neuropsychologia, 16(3), 332–340. https://doi.org/10.1590/1980-5764-dn-2022-0017

Ribeiro, Ó., Araújo, L., Figueiredo, D., Paúl, C., & Teixeira, L. (2021). The Caregiver Support Ratio in Europe: Estimating the future of potentially (Un)Available caregivers. Healthcare, 10(1), 11. https://doi.org/10.3390/healthcare10010011

Feast A, Moniz-Cook E, Stoner C, Charlesworth G, Orrell M.A systematic review of the relationship between behavioral and psychological symptoms (BPSD) and caregiver well-being. International Psychogeriatrics. 2016;28(11):1761-1774. doi:10.1017/S1041610216000922

Nourhashémi, F., Andrieu, S., Sastres, N., Ducassé, J., Lauque, D., Sinclair, A. J., Albarède, J. L., & Vellas, B. (2001). Descriptive analysis of emergency hospital admissions of patients with Alzheimer disease. Alzheimer Disease & Associated Disorders, 15(1), 21–25. https://doi.org/10.1097/00002093-200101000-00003

Toot, S., Swinson, T., Devine, M., Challis, D., & Orrell, M. (2016). Causes of nursing home placement for older people with dementia: A Systematic review and meta-analysis. International Psychogeriatrics, 29(2), 195–208. https://doi.org/10.1017/s1041610216001654

Yaffe K, Fox P, Newcomer R, Sands L, Lindquist K, Dane K, Covinsky KE. Patient and caregiver characteristics and nursing home placement in patients with dementia. JAMA. 2002 Apr 24;287(16):2090-7. doi:10.1001/jama.287.16.2090. PMID: 11966383.

Beeri, M. S., Werner, P., Davidson, M., & Noy, S. (2002). The cost of Behavioral and Psychological Symptoms of Dementia (BPSD) in community dwelling Alzheimer's disease patients. International Journal of Geriatric Psychiatry, 17(5), 403–408. https://doi.org/10.1002/gps.490

Kales, H. C., Kern, V., Kim, H. M., & Blazek, M. (2020). Moving Evidence-Informed Assessment and Management of Behavioral and Psychological Symptoms of Dementia into the Real World: Training Family and Staff Caregivers in the DICE Approach. The American Journal of Geriatric Psychiatry, 28(12), 1248–1255. https://doi.org/10.1016/j.jagp.2020.08.008

Hird, N., Osaki, T., Ghosh, S., Palaniappan, S. K., & Maeda, K. (2023). Enabling personalization for digital cognitive stimulation to support communication with people with dementia: a pilot intervention study as a prelude to AI development (Preprint). JMIR Formative Research. https://doi.org/10.2196/51732

Moyle, W. (2019). The promise of technology in the future of dementia care. Nature Reviews. Neurology, 15(6), 353–359. https://doi.org/10.1038/s41582-019-0188-y

Astell, A., Bouranis, N., Hoey, J., Lindauer, A., Mihailidis, A., Nugent, C., Robillard, J. M., & Area, D. P. I. (2019). Technology and Dementia: The Future is Now. Dementia and Geriatric Cognitive Disorders, 47(3), 131–139. https://doi.org/10.1159/000497800

Barbosa, A., Ferreira, A. R., Smits, C., Hegerath, F., Vollmar, H. C., Fernandes, L., Craven, M. P., Innes, A., Casey, D., Sezgin, D., Hopper, L., & Øksnebjerg, L. (2023). Use and uptake of technology by people with dementia and their supporters during the COVID-19 pandemic. Aging and Mental Health/Aging & Mental Health, 28(1), 83–94. https://doi.org/10.1080/13607863.2022.2163375

Maust, D. T., Kim, H. M., Seyfried, L. S., Chiang, C., Kavanagh, J., Schneider, L. S., & Kales, H. C. (2015). Antipsychotics, other psychotropics, and the risk of death in patients with dementia. JAMA Psychiatry, 72(5), 438. https://doi.org/10.1001/jamapsychiatry.2014.3018

Kales, H. C. (2015). Common Sense: addressed to geriatric psychiatrists on the subject of behavioral and psychological symptoms of dementia. The American Journal of Geriatric Psychiatry, 23(12), 1209–1213. https://doi.org/10.1016/j.jagp.2015.10.001

Brodaty, H., & Arasaratnam, C. (2012). Meta-Analysis of nonpharmacological interventions for neuropsychiatric symptoms of dementia. The American Journal of Psychiatry, 169(9), 946–953. https://doi.org/10.1176/appi.ajp.2012.11101529

De Oliveira, A. M., Radanovic, M., De Mello, P. C. H., Buchain, P. C., Vizzotto, A. D. B., Celestino, D. L., Stella, F., Piersol, C. V., & Forlenza, O. V. (2015). Nonpharmacological interventions to Reduce behavioral and psychological Symptoms of dementia: a systematic review. BioMed Research International, 2015, 1–9. https://doi.org/10.1155/2015/218980

Park, K., Lee, S., Yang, J., Song, T., & Hong, G.-R. S. (2019). A systematic review and meta-analysis on the effect of reminiscence therapy for people with dementia. International Psychogeriatrics, 31(11), 1581–1597. doi:10.1017/S1041610218002168

Cai, Y., Li, L., Xu, C., & Wang, Z. (2020). The Effectiveness of Non-Pharmacological Interventions on Apathy in Patients with Dementia: A systematic review of systematic reviews. Worldviews on Evidence-based Nursing, 17(4), 311–318. https://doi.org/10.1111/wvn.12459

Burley, C. V., Livingston, G., Knapp, M. R. J., Wimo, A., Norman, R., & Brodaty, H. (2020). Time to invest in prevention and better care of behaviors and psychological symptoms associated with dementia. International Psychogeriatrics, 32(5), 567–572. doi:10.1017/S104161022000037X

Kales, H. C., Gitlin, L. N., & Lyketsos, C. G. (2014). Management of Neuropsychiatric Symptoms of Dementia in Clinical Settings: Recommendations from a Multidisciplinary Expert Panel. Journal of the American Geriatrics Society, 62(4), 762–769. https://doi.org/10.1111/jgs.12730

Xygkou. (2024). MindTalker: Navigating the Complexities of AI-Enhanced Social Engagement for People with Early-Stage Dementia. ACM 2024 (Association of Computing Machinery) CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3613904.3642538

Tschang, F., & Almirall, E. (2021). Artificial intelligence as Augmenting Automation: Implications for employment. Academy of Management Perspectives, 35(4), 642–659. https://doi.org/10.5465/amp.2019.0062

Coughlin, J. F., & Lau, J. (2006). Cathedral builders wanted: Constructing a new vision of technology for old age. Public Policy & Aging Report, 16(1), 4–8. https://doi.org/10.1093/ppar/16.1.4

Blazer, D. G., Domnitz, S., & Liverman, C. T. (2016). Hearing health care for adults. In National Academies Press eBooks. https://doi.org/10.17226/23446

Chabot, M., Delaware, L., McCarley, S., Little, C., Nye, A. H., & Anderson, E. E. (2019). Living In Place: the Impact of Smart Technology. Current Geriatrics Reports, 8(3), 232–238. https://doi.org/10.1007/s13670-019-00296-4

Labonnote, N., & Høyland, K. (2015). Smart home technologies that support independent living: challenges and opportunities for the building industry – a systematic mapping study. Intelligent Buildings International, 9(1), 40–63. https://doi.org/10.1080/17508975.2015.1048767

Morris, M. E., Adair, B., Ozanne, E., Kurowski, W., Miller, K. J., Pearce, A. J., Santamaria, N., Long, M., Ventura, C., & Said, C. M. (2014). Smart technologies to enhance social connectedness in older people who live at home. Australasian Journal on Ageing, 33(3), 142–152. https://doi.org/10.1111/ajag.12154

Ma, C., Guerra-Santin, O., & Mohammadi, M. (2021). Smart home modification design strategies for ageing in place: a systematic review. Journal of Housing and the Built Environment, 37(2), 625–651. https://doi.org/10.1007/s10901-021-09888-z

Topol, E. J. (2019b). High-performance medicine: the convergence of human and artificial intelligence. Nature Medicine, 25(1), 44–56. https://doi.org/10.1038/s41591-018-0300-7

Huddle, M., Kellar, J., Srikumar, K., Deepak, K., & Martines, D. (2023). Generative AI will transform health care sooner than you think. Boston Consulting Group. https://www.bcg.com/publications/2023/how-generative-ai-is-transforming-health-care-sooner-than-expected

Hallqvist, J. (2021). The making of a professional digital caregiver: personalisation and friendliness as practices of humanisation. Medical Humanities, 48(3), 347–356. https://doi.org/10.1136/medhum-2020-011975

Linardon, J., Cuijpers, P., Carlbring, P., Messer, M., & Fuller-Tyszkiewicz, M. (2019). The efficacy of app-supported smartphone interventions for mental health problems: a meta-analysis of randomized controlled trials. World Psychiatry, 18(3), 325–336. https://doi.org/10.1002/wps.20673

Carlbring, P., Andersson, G., Cuijpers, P., Riper, H., & Hedman-Lagerlöf, E. (2017). Internet-based vs. face-to-face cognitive behavior therapy for psychiatric and somatic disorders: an updated systematic review and meta-analysis. Cognitive Behaviour Therapy, 47(1), 1–18. https://doi.org/10.1080/16506073.2017.1401115

Leo, A. J., Schuelke, M. J., Hunt, D., Metzler, J. P., Miller, J. P., Areán, P. A., Armbrecht, M. A., & Cheng, A. L. (2022). A Digital Mental health intervention in an orthopedic setting for patients with symptoms of depression and/or anxiety: Feasibility Prospective Cohort study. JMIR Formative Research, 6(2), e34889. https://doi.org/10.2196/34889

Graham, S., Depp, C., Lee, E. E., Nebeker, C., Tu, X., Kim, H.-C., & Jeste, D. V. (2019). Artificial intelligence for mental health and mental illnesses: An overview. Current Psychiatry Reports, 21(11). https://doi.org/10.1007/s11920-019-1094-0

Izumi, K., Tanaka, H., Shidara, K., Adachi, H., Kanayama, D., Kudo, T., & Nakamura, S. (2024). Response Generation for Cognitive Behavioral Therapy with Large Language Models: Comparative Study with Socratic Questioning. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2401.15966

Cascella, M., Montomoli, J., Bellini, V., & Bignami, E. (2023). Evaluating the feasibility of CHATGPT in Healthcare: An analysis of multiple clinical and research scenarios. Journal of Medical Systems, 47(1). https://doi.org/10.1007/s10916-023-01925-4

Inkster, B., Sarda, S., & Subramanian, V. (2018). An Empathy-Driven, Conversational Artificial Intelligence Agent (Wysa) for Digital Mental Well-Being: Real-World Data Evaluation Mixed-Methods Study. JMIR Mhealth Uhealth, 6(11), e12106. https://doi.org/10.2196/12106

Sarker, I. H. (2022). AI-Based modeling: techniques, applications and research issues towards automation, intelligent and smart systems. SN Computer Science, 3(2). https://doi.org/10.1007/s42979-022-01043-x

Korteling, J. E. (Hans)., van de Boer-Visschedijk, G. C., Blankendaal, R. A. M., Boonekamp, R. C., & Eikelboom, A. R. (2021). Human- versus Artificial Intelligence. Frontiers in Artificial Intelligence, 4. https://www.frontiersin.org/articles/10.3389/frai.2021.622364. DOI: 10.3389/frai.2021.622364. ISSN: 2624-8212.

Gao, Y., Xiong, Y., Gao, X., Jia, K., Pan, J., Bi, Y., Yi, D., Sun, J., & Wang, H. (2023). Retrieval-Augmented Generation for Large Language Models: A survey. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2312.10997

Nicodème, C. (2020). Build confidence and acceptance of AI-based decision support systems - explainable and liable AI. 13th International Conference on Human System Interaction (HSI). https://doi.org/10.1109/hsi49210.2020.9142668

Zhang, Y., Li, Y., Cui, L., Cai, D., Liu, L., Fu, T., Huang, X., Zhao, E., Zhang, Y., Chen, Y., Wang, L., Luu, A. T., Bi, W., Shi, F., & Shi, S. (2023). Siren's Song in the AI Ocean: A survey on hallucination in large Language models. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2309.01219

Lewis, P., Perez, E., Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., Küttler, H., Lewis, M., Yih, W., Rocktäschel, T., Riedel, S., & Kiela, D. (2020). Retrieval-Augmented Generation for Knowledge-Intensive NLP tasks. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2005.11401

Wang, C., Ong, J., Wang, C. Y. J., Ong, H., Cheng, R. R., & Ong, D. (2023). Potential for GPT Technology to optimize future clinical Decision-Making using Retrieval-Augmented

Generation. Annals of Biomedical Engineering. https://doi.org/10.1007/s10439-023-03327-6

Pouplin, T., Sun, H., Holt, S., & Van Der Schaar, M. (2024). Retrieval-Augmented Thought Process as Sequential decision making. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2402.07812

Levick, D., Saldana, L., Teich, J. M., Osheroff, J. A., Velasco, F. T., Sittig, D. F., Rogers, K. M., & Jenders, R. A. (2012). Improving Outcomes with Clinical Decision Support: An Implementer's Guide, Second Edition. Himss Publishing.

Ong, J. C. L., Li, J., Elangovan, K., Lim, G., Lim, D. Y. Z., Sng, G. G. R., Ke, Y., Tung, J. Y. M., Zhong, R. J., Koh, C. M. Y., Lee, K. Z. H., Xiang, C., Ch'ng, J. K., Than, A., Goh, J. P. N., & Ting, D. S. W. (2024). Development and testing of a novel Large Language Model-Based Clinical Decision Support Systems for medication safety in 12 clinical specialties. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2402.01741

Bleher, H., & Braun, M. (2022). Diffused responsibility: attributions of responsibility in the use of AI-driven clinical decision support systems. AI And Ethics, 2(4), 747–761. https://doi.org/10.1007/s43681-022-00135-x

Lysaght, T., Lim, H. Y., Xafis, V., & Ngiam, K. Y. (2019). AI-Assisted Decision-making in healthcare. Asian Bioethics Review, 11(3), 299–314. https://doi.org/10.1007/s41649-019-00096-0

Martinez-Martin, N. (2021). Minding the AI: Ethical challenges and practice for AI mental health care tools. In Advances in Neuroethics (pp. 111–125). Springer International Publishing. https://doi.org/10.1007/978-3-030-74188-4_8

Raisch, S., & Krakowski, S. (2021). Artificial Intelligence and Management: The Automation–Augmentation Paradox. Academy of Management Review, 46(1), 192–210. https://doi.org/10.5465/amr.2018.0072

Wagholikar, K. B., Sundararajan, V., & Deshpande, A. (2011). Modeling Paradigms for Medical Diagnostic Decision Support: A survey and Future Directions. Journal of Medical Systems, 36(5), 3029–3049. https://doi.org/10.1007/s10916-011-9780-4

Billis, A., Papageorgiou, E. I., Frantzidιs, C. A., Tsatali, M., Tsolaki, A., & Bamidis, P. D. (2015). A Decision-Support framework for promoting independent living and ageing well. IEEE Journal of Biomedical and Health Informatics (Print), 19(1), 199–209. https://doi.org/10.1109/jbhi.2014.2336757

Blake, A., & Carroll, B. T. (2016). Game theory and strategy in medical training. Medical Education, 50(11), 1094–1106. https://doi.org/10.1111/medu.13116

Dixit, A. (2005). Restoring fun to game theory. The Journal of Economic Education, 36(3), 205–219. https://doi.org/10.3200/jece.36.3.205-219

DeSanctis, G., & Gallupe, R. B. (1987). A foundation for the study of group decision support systems. Management Science, 33(5), 589–609. https://doi.org/10.1287/mnsc.33.5.589

Bendig, E., Erb, B., Schulze-Thuesing, L., & Baumeister, H. (2019). The next generation: Chatbots in Clinical Psychology and Psychotherapy to Foster Mental Health – A scoping review. Verhaltenstherapie, 32(Suppl. 1), 64–76. https://doi.org/10.1159/000501812

Miao, B., Almaraz, E. R., Ganjouei, A. A., Suresh, A., Zack, T., Bravo, M., Raghavendran, S., Oskotsky, B., Alaa, A. M., & Butte, A. J. (2024). Generation of guideline-based clinical decision trees in oncology using large language models. medRxiv (Cold Spring Harbor Laboratory). https://doi.org/10.1101/2024.03.04.24303737

Hua, J., Zhu, H., Wang, F., Liu, X., Lu, R., Li, H., & Zhang, Y. (2019). CINEMA: Efficient and Privacy-Preserving Online Medical Primary Diagnosis with Skyline Query. IEEE Internet of Things Journal, 6(2), 1450–1461. https://doi.org/10.1109/jiot.2018.2834156

Azar, A. T., & El-Metwally, S. M. (2012). Decision tree classifiers for automated medical diagnosis. Neural Computing and Applications, 23(7–8), 2387–2403. https://doi.org/10.1007/s00521-012-1196-7

P. Kulkarni, A. Mahabaleshwarkar, M. Kulkarni, N. Sirsikar and K. Gadgil, "Conversational AI: An Overview of Methodologies, Applications & Future Scope," 2019 5th International Conference On Computing, Communication, Control And Automation (ICCUBEA), Pune, India, 2019, pp. 1-7, doi: 10.1109/ICCUBEA47591.2019.9129347.

D. S. Rosas, S. T. Arriaga and M. A. A. Fernández, "Search for Dementia Patterns in Transcribed Conversations using Natural Language Processing," 2019 16th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), Mexico City, Mexico, 2019, pp. 1-6, doi: 10.1109/ICEEE.2019.8884572.

Shumanov, M., & Johnson, L. W. (2021). Making conversations with chatbots more personalized. Computers in Human Behavior, 117, 106627. https://doi.org/10.1016/j.chb.2020.106627

Fried, B. H. (2020). Rawls, risk, and the maximin principle. Facing up to scarcity: The logic and limits of nonconsequentialist thought, 149.

Harsanyi, J. C. (1975). Can the Maximin Principle Serve as a Basis for Morality? A Critique of John Rawls's Theory. The American Political Science Review, 69(2), 594–606. https://doi.org/10.2307/1959090

Brody, H., & Thompson, J. (1981). The maximin strategy in modern obstetrics. PubMed, 12(6), 977–986. https://pubmed.ncbi.nlm.nih.gov/7014759

Kosugi, N., Shimizu, S., Kazui, H., Sato, S., Yoshiyama, K., Kamimura, N., Nagakura, W., Ikeda, Y., & Ikeda, M. (2021). Automatic grouping and text data augmentation about behavioral and psychological symptoms of dementia in Ninchisho Chienowa-net. iiWAS2021: The 23rd International Conference on Information Integration and Web Intelligence. https://doi.org/10.1145/3487664.3487697

Park, Y., Pillai, A., Deng, J., Guo, E., Gupta, M., Paget, M., & Naugler, C. (2024). Assessing the research landscape and clinical utility of large language models: a scoping review. BMC Medical Informatics and Decision Making, 24(1). https://doi.org/10.1186/s12911-024-02459-6

Ouyang, L., Wu, J., Jiang, X., Almeida, D., Wainwright, C. L., Mishkin, P., Zhang, C., Agarwal, S., Slama, K., Ray, A., Schulman, J., Hilton, J., Kelton, F., Miller, L., Simens, M., Askill, A., Welinder, P., Christiano, P., Leike, J., . . . OpenAI. (2022). Training language models to follow instructions with human feedback. In OpenAI [Journal-article]. https://proceedings.neurips.cc/paper_files/paper/2022/file/b1efde53be364a73914f58805a001731-Paper-Conference.pdf

Ding, P., Kuang, J., Ma, D., Cao, X., Xian, Y., Chen, J., & Huang, S. (2023). A Wolf in Sheep's Clothing: Generalized Nested Jailbreak Prompts can Fool Large Language Models Easily. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2311.08268

Ahmad, M., Yaramic, I., & Roy, T. D. (2023). Creating Trustworthy LLMs: Dealing with Hallucinations in Healthcare AI. Arxiv. https://doi.org/10.20944/preprints202310.1662.v1 Dong, X. L. (2024). The Journey to A Knowledgeable Assistant with Retrieval-Augmented Generation (RAG). WSDM '24: Proceedings of the 17th ACM International Conference on Web Search and Data Mining. https://doi.org/10.1145/3616855.3638207

4 Smart homes & inclusive communities: **Conference paper**

Living labs for impact in community-based health promotion

Working together in research, education and practice

Karin, Dijkstra[1*]

[1] Research Group Smart Health, Saxion University of Applied Sciences, The Netherlands

* Corresponding author: Karin Dijkstra (k.dijkstra@saxion.nl)

Abstract: This paper addresses the societal challenges in the field of health promotion and how the living environment and living labs play a key role. Living labs emphasize collaborative efforts, knowledge sharing, and mutual learning across research, education, and professionals. By uniting researchers, students, professionals, and citizens there is an opportunity to effectively address these challenges and transforming living environments into living labs. Four types of living labs are presented addressing different societal challenges related to community-based health promotion. For each living lab a short description explained the aim of the lab; the collaborating partners in practice, research and education; who initiated the lab; which research questions are addressed and some initial results. Results showed that living labs can originate from initiatives from research, education and practice/citizens and all addressed challenges related to more inclusive and healthier environments. Despite these very different starting points, they can contribute to (1) generating scientific knowledge on topics related to community-based health promotion, (2) the health and well-being of citizens, (3) the development of practice, and (4) the education of students. This paper thus demonstrates how living labs can work as the proposed catalysts for healthier and more inclusive environments.

Keywords: living labs; healthy environments; resilient communities; physical activity; social participation

1. Introduction

Health promotion is an increasingly important topic for professionals in healthcare and social care, as well as the individual citizen or patient. In this paper, I will address the challenges in the field of health promotion and how the living environment and living labs play a key role in this domain. I will do this by first outlining the complexity of the societal issue of health promotion. To do this, I will address health disparities in the context of health promotion. It becomes clear that the living environment plays a crucial role and that the individual without a healthy living environment, has significantly less chance of successful behaviour change related to health promotion. And most importantly, I will demonstrate the potential of living labs as catalysts for healthier and more inclusive environments.

1.1 Health promotion, prevention and inequality

How healthy you are, as well as how healthy you feel, is largely determined by your lifestyle. Whether you eat healthy, smoke, exercise enough, but also how much stress you have, and whether you sleep enough are all related to health. In the Netherlands, about 50% of people are overweight and almost half do not move or exercise enough (Kloosterman et al., 2023). With the predicted increase in people suffering from lifestyle-related diseases and the expected shortages of both professionals and informal caregivers in healthcare, the urgency is clear: it's time for health promotion and preventing illness. But what is health promotion? Health promotion is about the process through which individuals or groups gain increasing control over the determinants of health, enabling them to stay healthy or improve their health (Nutbeam & Muscat, 2021). Health promotion is complex, both at the level of the individual and that of their living environment.

In the Netherlands, we have a growing group of people at risk of lifestyle-related conditions: individuals with overweight who do not exercise enough. And although this picture applies to Dutch society as a whole, we still see that these health risks are greater and more prevalent among groups characterized by a lower socioeconomic status (SES). Factors such as healthy eating, sufficient exercise, not smoking, or getting enough sleep are largely dependent on other factors in your life. Where you grew up, the level of education you were able to pursue, your income, where you live, and your social network all play a significant role. This leads to socioeconomic health disparities (SEHD), systematic differences in health and life expectancy depending on one's position in society, often expressed in terms of socioeconomic status. We see these SEHD not only reflected in people's life expectancy but also in the number of years lived in experienced good health. And with all societal transitions, socioeconomic health disparities are likely to increase rather than decrease. Consider, for example, how the energy transition puts everyone under (financial) pressure, but affects the more vulnerable groups in our society even harder.

In the field of health promotion, there has been a shift from focusing solely on the individual to broader attention to environmental, social, and political factors as determinants of health (Van den Broucke, 2014). With this shift, a focus on behavioural interventions at the individual level may not seem appropriate, even though interventions at the individual level often appear to be the norm. By focusing solely on individual behavioural interventions, one ignores the complexity of the system surrounding the individual, which often has a much greater influence. At the same time, when an individual fails to successfully change their own behaviour, blame is often placed on the individual. Yet, a healthy lifestyle is largely influenced by the aforementioned socioeconomic position. Factors such as poverty, stress, and an unhealthy living environment make it nearly impossible to achieve successful lifestyle changes. Collaborating with citizens and truly understanding the position they find themselves in can help in providing adequate support for lifestyle change and living labs provide the context for this collaboration.

1.2 Healthy living environments

A healthy living environment is an environment that is experienced as pleasant, encourages healthy behaviour, and where the pressure on the healthcare system is kept as low as possible. The environment in which people live influences their health where the physical layout and social structures have the potential to tempt people to exercise, make healthy choices, relax, or meet each other. The living environment of people is a relatively constant factor, providing the opportunity for lasting behaviour change, for instance, by incorporating exercise into one's daily routine (Maher et al., 2021). But currently, most living environments can still be best characterized as obesogenic environments. An obesogenic environment is one that encourages people to overeat and, additionally, to exercise too little. This obesogenic environment ultimately needs to be addressed and requires societal behaviour change, and the involvement of the government is indispensable (De Brauw, 2021). Addressing these challenges requires collaboration across policy domains such as health and the spatial domain (Korfmacher, 2020). A good example is the health in all policies approach (Greer et al., 2022), which for example ensures that health is considered in the spatial policy decision-making process. This means that for example issues related to climate adaptation can lead to win-win situations. Increasing green spaces in neighbourhoods can contribute to reducing waterlogging and heat stress, while simultaneously creating a more appealing living environment contributing to physical activity and social interaction.

1.3 From living environments to living labs

These challenges in our society and in community-based health promotion specifically can be addressed in living labs. Living Labs are defined as spaces for innovative and participative research, development and activity deployment by the use of multi-disciplinary methods and approaches and thereby bringing people together in social contexts around different themes" (Mastelic, Sahakian, & Bonazzi, 2015). Living labs are thus characterised by the importance of collaboration, sharing knowledge, and learning from each other, in terms of research, education and professional practice. Bringing together researchers, students, professionals and citizens, geographically situated in the living environment of these citizen facing the challenges, provides the opportunity to address these challenges and transforming the living environment into a living lab.

2. Methods

In this paper I will present four types of living labs (n=6) addressing different societal challenges related to community-based health promotion. For each living lab a short description will explain the aim of the lab; the collaborating partners in practice, research and education; who initiated the lab; which research questions are addressed and some initial results if available. This information will be presented in a table to provide insight, by means of a qualitative description, into shared characteristics and differences and how these may be linked to the potential impact of the living lab on healthier and more inclusive neighbourhoods. Since three of the six described living labs started in 2024 it is considered premature to identify effective mechanisms.

3. Results and analysis

3.1 Living labs "sports and physical activity"

In these living labs (n = 3), various partners collaborate with residents to develop an innovative approach to increase sports and physical activity participation in the neighbourhood, where many people reside in a vulnerable socioeconomic position (SEP). Research shows that sports and physical activity have a positive influence on health, for example, in combating obesity and in preventing and treating (chronic) conditions such as diabetes and cardiovascular diseases (Bailey et al., 2013). Additionally, a recent study indicated that if more residents meet the physical activity guidelines, this has a positive effect on healthcare costs within a neighbourhood, particularly in low socioeconomic status (SES) areas (de Boer et al., 2022). These labs therefore address the societal challenges related to health promotion by physical activity and SEHD. The aim is to inspire more people to be physically active, who currently do not (sufficiently) engage in sports and physical activity, thereby achieving potential health improvements.

The research questions are aimed to gain insight into how sports and physical activity participation among people in a vulnerable socioeconomic position (SEP) can be increased. We address questions like (1) What are the desires, needs, and motivations of people in a vulnerable SEP regarding a sports and/or physical activity program, (2) which barriers and facilitating factors are experienced by the target group in the current sports and/or physical activity offerings; and (3) how do you align with the SEP of people in terms of offerings, language use, and affordability?

3.2 Living lab "social health"

This living lab is located in a neighbourhood that is often described as being 'vulnerable'. We started a living lab as part of a post-doc research project and collaborate with partners from professional organisations and other relevant stakeholders in this community. The main aim was to improve the social health of the citizens. Social health can be characterized by three dimensions: (1) having the capacity to fulfil one's potential and obligations; (2) the ability to manage life with some degree of independence, despite a medical condition; and (3) participation in social activities (Huber et al. 2011).

From the start of the project this living lab was also the location where education took place. Groups of students working on interdisciplinary projects worked with a group of elderly women with a migration background on challenges related to the social health and well-being of these women. Currently ,students from a variety of teaching programs contribute to this project and we now have a learning community with 24 participating students. This living lab provides the setting for practice-based research on community-based health promotion and offers the infrastructure to address important challenges as identified by the community itself. And by the collaboration in this neighbourhood, we showcase small victories. For instance, there were disappointed women when there was suddenly no physical activity on the program, despite their initial hesitance to participate. This demonstrates how we can take initial steps towards behaviour change and health from both the physical and social living environment. Moreover, based on the successful approach and collaboration in this neighbourhood, this neighbourhood was selected to be the location of one of the recently started labs on sports and physical activity.

3.3 Living lab “resilient community”

This living lab is an experimental space for policy, community teams, social welfare work, and the social domain to strengthen preventive efforts. Social welfare work plays a significant role here. The living lab focuses on the question of how we can better identify vulnerabilities among residents and how we can strengthen resilience (in all its aspects) in a timely manner so that people do not encounter subsequent (and often related) problems. This living lab was initiated by a welfare organisation with the ambition to demonstrate how a different way of community-based working can result in demonstrable changes in terms of costs associated with health and care. The social innovation project will run for 3 years and will be accompanied by a continuous monitoring and evaluation track, thereby having a strong research focus, but with partners from practice in the lead.

3.4 Living lab “happy neighbourhood”

This citizen initiative has become an outstanding example of how to positively impact the lives of people in a community-setting. The aim of this citizen initiative is, together with partners, to create a mini-society in the neighbourhood where people meet, develop themselves, and gain more control over their lives. The initiative has developed a methodology in which literally and figuratively "getting into motion" takes the centre stage. The focus is on Health and Behaviour rather than on Illness and Care. In addition to taking a much more positive way to approach health, this movement supports keeping healthcare affordable and feasible in the long term. During the past years, as researchers from a university of applied sciences, we carried out various research and education-based projects in this community. Working from an action research perspective, we follow the lead of the stakeholders and citizens and together identify opportunities to address research questions. By collaborating and becoming part of the initiative we may also consider this a living lab. With the clear distinction that is was not defined as such from the start. This presents another way of looking at living labs and how to get involved in local initiatives and initiating projects bringing together practice, education and research. One of the projects that included research demonstrated how important the role of the living environment is. A preliminary finding is that people participating in citizen initiatives such as "Buurtgeluk"[1] feel a sense of belonging and recognition, and only after these needs are being fulfilled, they can start working on a healthier lifestyle.

Table 1. Analysis characteristics of the living labs

Living labs	Origins of the initiative	Partners	Collaboration research, education and practice	Societal challenge	Aim	Research questions
Living labs "sports and physical activity" (n=3)	Research project (n=1) and governmental body (n=2)	(local) government Welfare organisations Sports organisations	Research Education Practice	Physical activity and SEHD	Inspire more people to be physically active who currently do not (sufficiently) engage in sports and physical activity, thereby achieving potential health improvements	(1) What are the desires, needs, and motivations of people in a vulnerable SEP regarding a sports and/or physical activity program, (2) which barriers and facilitating factors are experienced by the target group in the current sports and/or physical activity offerings; and (3) how do you align with the SEP of people in terms of offerings, language use, and affordability?
Living lab "social health"	Research project	Local government / Professionals in health and care	Research Education Practice	Social health, participation, SEHD	Improve social health	How can we improve the social health of elderly with a migration background in the setting of a living lab?
Living lab "resilient community"	Welfare organisation	(local) government / Professionals in health and care	Research Practice	Prevention and SEHD	Develop a different way of community-based working and moving towards prevention	Results a different way of community-based working in demonstrable changes in terms of costs associated with health and care?
Living lab "Happy Neighbourhood"	Citizen initiative	Citizens Professionals in health and care	Research Education Practice	Transformation in health and care	create a mini-society in the neighbourhood where people meet, develop themselves, and gain more control over their lives	Defined in short cycles as part of a participative action research approach

4. Discussion

Social challenges such as reducing socioeconomic health disparities are complex issues. Living labs can provide the context to combine research and education to contribute to these challenges as underlined by the way we address various challenges in the described living labs. Despite obvious challenges in terms of for example teaching schedules or the pace of research compared to the desire of practice to speed up the process, these living labs show that collaboration between partners in research, education and practice is a feasible option. The results also show that living labs can originate from initiatives from research, education and practice/citizens and all address challenges related to more inclusive and healthier environments. And despite these very different starting points, they can all contribute to (1) generating scientific knowledge on topics related to community-based health promotion, (2) the health and well-being of citizens, (3) the development of practice, and (4) the education of students.

From this educational perspective, students in healthcare and welfare can already contribute to solving these issues during their education and be prepared for future professional practice. By engaging with residents, students learn to understand the complex context of people in vulnerable situations. This involves achieving an equal relationship between residents, students, neighbourhood professionals, teachers, and researchers

based on reciprocity and equitable dialogue. This in turn facilitates a joint learning process on how to promote residents' health and therefore an approach that fits with working in living labs aimed to improve community-based health promotion.

From a research perspective, the described living labs demonstrate that collaborating in living labs can be relevant in the various stages of practice-oriented research. Presence in the actual living environment of citizens has the potential to provide valuable insights during the exploratory stages of research projects and ensuring that the actual research questions are the ones that need to be addressed. In the next stage, living labs provide the setting to develop interventions in co-creation with its users, both citizens and health and care professionals. Living labs also provide the real-life setting that is ideal to evaluate the develop interventions.

5. Conclusion

Research, education, professionals in practice, and citizens can benefit from being part of living labs. The importance of collaboration, sharing knowledge, and learning from each other are characteristics of all described living labs. This paper thus demonstrates the potential of living labs as catalysts for healthier and more inclusive environments.

Acknowledgements

The author would like to thank the team working on community-based health promotion at Saxion University of Applied Sciences: Nicole Ketelaar, Noortje Rijken, Yvonne Kerkhof, Elke ter Huurne, Sarah Ros, Sara Laurijssen, Helen Meijrink and Danique Hofstee. Their projects contributed, directly or indirectly, to the described living labs. These living labs would not be possible without collaborating with partners from practice, among which Stichting Erwelzijn and Buurtgeluk. The author is also grateful for the collaboration with Gitte Kloek on making living labs the next step in both research and education at Saxion.

References

Bailey, R., Hillman, C., Arent, S., & Petitpas, A. (2013). Physical activity: an underestimated investment in

human capital?. Journal of physical activity and health, 10(3), 289-308. https://doi.org/10.1123/jpah.10.3.289

de Boer, W. I. (2022). Sport as a medicine for health and health inequalities (Doctoral dissertation, Groningen: Rijksuniversiteit Groningen).

Van den Broucke, S. (2014). Needs, norms and nudges: the place of behaviour change in health promotion.

Health Promotion International, 29(4), 597-600.

Greer, S. L., Falkenbach, M., Siciliani, L., McKee, M., Wismar, M., & Figueras, J. (2022). From health in all

policies to health for all policies. The lancet public health, 7(8), e718-e720.

L.M. de Brauw (2021). De gecombineerde leefstijlinterventie. Een papieren tijger in de strijd tegen obesitas?

[Intensive lifestyle interventions: are they effective against obesity?] Nederlands Tijdschrift Voor

Geneeskunde, 165, D5885

Health~Holland (2021). +5, -30 Toekomstbeelden 2030 [Future Images 2030]. Available at:

https://www.health-holland.com/about-us/publications/toekomstbeelden-2030

Huber, M., Knottnerus, J. A., Green, L., Van Der Horst, H., Jadad, A. R., Kromhout, D., ... & Smid, H. (2011).

How should we define health?. Bmj, 343.

Kerkhof, Y., Jukema, J., Dijkstra, K. & Van Os-Medendorp, H. (2023). Samen ontwikkelen en leren voor betere

gezondheid in de wijk. Sozio, https://www.sociaaldigitaal.nl/p/samen-ontwikkelen-en-leren-voor-betere gezondheid-in-de-wijk/8101

Kloosterman, R., Akkermans, M., Reep, C., Tummers-van der AA, M. (2023). (On)gezonde leefstijl 2022:

opvattingen, motieven en gedragingen [(Un)healthy lifestyle 2022: opinions, motives and behaviour].

Available at: https://www.cbs.nl/nl-nl/longread/rapportages/2023/on--gezonde-leefstijl-2022-opvattingen-motieven-en-gedragingen

Korfmacher, K. S. (2020). Bridging Silos: A research agenda for local environmental health initiatives. NEW

SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 30(3), 173-182.

Maher, J. P., Rebar, A. L., & Dunton, G. F. (2021). The influence of context stability on physical activity and

sedentary behaviour habit and behaviour: An ecological momentary assessment study. British Journal of Health Psychology, 26(3), 861-881.

Mastelic, J., Sahakian, M., & Bonazzi, R. (2015). How to keep a living lab alive?. info, 17(4), 12-25.

Nutbeam, D., & Muscat, D. M. (2021). Health promotion glossary 2021. Health Promotion International,36(6), 1578-1598.

4 Smart homes & inclusive communities: **Conference paper**

Space for Adoption: Exploring the adoption and sustained use of smart environments in dementia care facilities

Masi Mohammadi[1, 2]*, Coosje Hammink[2], Ruth Bles[3]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

* Corresponding author: Masi Mohammadi (m.mohammadi@tue.nl)

Abstract: The adoption of smart interactive environments in nursing homes is growing, reflecting their potential to enhance social interaction, agency, and reduce behavioural problems among people with dementia. Despite this potential, these technologies often remain underutilized after initial deployment. This study explores the factors influencing the adoption and sustained use of such technologies, aiming to bridge the gap between their capabilities and actual use through targeted operational mechanisms and strategic interventions.

Employing a mixed-methods approach, this research integrates the extended Unified Theory of Acceptance and Use of Technology (UTAUT) model, enriched with insights from care professionals and observations of dynamics in care homes. It identifies significant barriers to technology utilization and proposes enhancements to the UTAUT model to better accommodate the complexities of dementia care. This study highlights the importance of addressing both technological and sociopsychological factors to facilitate technology integration within nursing homes. Findings include the development of customized strategies that promote durable technology adoption and the refinement of theoretical models to support effective integration. These contributions aim to influence both practice and policy, potentially alleviating caregiver burdens and improving patient outcomes through more effective use of technology. This expletory study underscores the need for a systemic and holistic approach to technology adoption in dementia care, ensuring that solutions are not only technically sound but also culturally and organizationally integrated within care settings.

Keywords: Smart Interactive environment, Dementia care, Nursing homes, Smart care, Technology adoption in healthcare

1. Introduction

In the Netherlands, approximately 290,000 individuals are currently living with dementia, a figure expected to rise to 620,000 by 2040 (Alzheimer Nederland, 2017; Alzheimer's Disease International, 2015). This increasing demographic pressure highlights the urgent need for effective care strategies, particularly as no curative or preventive pharmacological treatments are available for dementia (Huijsman, 2019; NHS, 2017; Servick, 2019). Consequently, nursing homes face the challenge of providing high-quality care to an increasingly complex care population that requires intensive support (Francke et al., 2018). Recent healthcare approaches, such as the positive health model (Huber et al., 2016) and the social approach to dementia, underscore the importance of holistic treatment that combines medical care with psychosocial support. These approaches advocate for a balance between physical care and psychosocial aspects such as well-being, purpose, and social interaction, promoting active involvement and stimulation of patients rather than passive caregiving (Campo & Chaudhury, 2012; Marquardt et al., 2014).

1.1 Integrating smart technologies in dementia care: challenges and opportunities

The significance of the care environment in maintaining quality of life and preventing misunderstood behaviours such as aggression and apathy in individuals with dementia is becoming increasingly evident (Campo & Chaudhury, 2012; Marquardt et al., 2014). In line with the transition from a predominantly medical to a psychosocial care model, there are increasingly examples of integrated technologies designed to stimulate residents cognitively, psychologically, socially, and physically. Studies demonstrate that technological advancements such as sensor technology and Artificial Intelligence are more frequently applied in caregiving, reducing care costs, alleviating caregiver burden, and simultaneously enhancing the autonomy and stimulation of end-users (Ferreira et al., 2016).

Increasingly, these technologies are embedded within the spatial context of nursing homes, serving functions such as fall prevention and monitoring the behaviour of individuals with dementia (Prins et al., 2018; Mohammadi, 2014). Often, these involve sensors embedded within the environment so that users are not burdened with actively operating the technology. Alongside the shift to a psychosocial care model, more examples of integrated technology aim to stimulate residents: cognitively, psychologically, socially, or physically. Various nursing homes are thus utilising these smart environments (Campo & Chaudhury, 2012; Marquardt et al., 2014; Ferreira et al., 2016; Jester Strategy, 2019; Vilans, 2020; Waardigheid en Trots, 2020).

Literature also reveals a nuanced view of technology acceptance among caregivers and individuals with dementia. Exposure to technology can alter perceived ease of use, potentially reducing resistance and enhancing usability perceptions (Burstein et al., 2015; Kramer et al., 2015). However, this exposure does not consistently affect other deep-rooted beliefs and attitudes towards technology, underscoring the complexity of changing attitudes (Dai et al., 2019). Kramer et al. (2015) emphasize how caregivers perceive the usability and utility of technology, significantly influencing their willingness to adopt technological aids.

The research highlights the importance of perceived ease of use as a crucial factor in technology acceptance, especially within the context of dementia care where straightforward interaction is essential for both caregivers and patients. Despite these barriers, actual usage is on the rise, suggesting that the tangible benefits of technology over time begin to outweigh initial reservations, leading to broader acceptance and integration of technological aids in care settings (Wanigatunga et al., 2015; Dai et al., 2019; Mohammadi, 2014). These interventions demonstrate the potential of technology to benefit individuals with dementia by accommodating their specific needs and enhancing their daily living conditions. Yet, resistance to change and technology anxiety are significant factors observed in various studies. Studies (Hammink et al., 2023) have shown that smart environments employing behavioural change mechanisms, such as facilitation and incentive motivation, specifically tailored to the individual needs and capabilities of people with dementia, can effectively support daily behaviour and positively influence mood and coping strategies, thereby enhancing quality of life.

Initial evaluations of these environments report positive feedback from care professionals, residents, and caregivers, noting a beneficial impact on the (misunderstood) behaviour of individuals with dementia (Meiland et al., 2012; Jamin et al., 2018; Braun et al., 2015). In practice, however, it turns out (Grave, 2019; Hammink et al., 2020; Grave & Mohammadi, 2018; Hammink et al., 2021) that these environments often 'gather dust' after a while; the 'embedding' or 'securing' of these smart environments does not seem to have taken place.

This is a well-known phenomenon in the technology adoption literature and is often observed in both the care sector and other sectors (Mendoza et al., 2005; Lumpe & Chambers, 2001). To further investigate this, the extended UTAUT model is used as a basis in this study (Venkatesh et al., 2003). This model enables the identification of factors that influence not only the intention but also the actual use. The central research question of this study is therefore: "Under what conditions can the acceptance and (sustainable) use of smart environments in the daily work of care professionals in nursing homes be increased?

2. Methods

This study, spanning from 2019 to 2024, employs a mixed-methods approach to explore the adoption and implementation of smart environments within the Dutch dementia care sector. Data collection integrates both qualitative insights through workshops and interviews, and quantitative data from observational studies.

During the annual national "New Living" (Het Nieuwe Wonen) conferences in 2019 and 2020, workshops were conducted with 30 sector experts to discuss the potential benefits and challenges of smart environments. These workshops used facilitated discussions and scenario-based planning to extract detailed insights on the expectations and real-world applications of these technologies in care settings.

From December 2020 to May 2021, detailed interviews were conducted with stakeholders from five Dutch care institutions involved in this study: tanteLouise, Oktober, Archipel, Vilente, and Ijsselheem. Each institution serves as a 'living lab', providing a dynamic research environment where technology integration was examined in real-time. Discussions focused on identifying operational barriers, such as digital literacy of the staff and structural impediments within each organization. Observations were carried out in late 2021 and early 2022 at psychogeriatric departments of two livinglabs. These non-intrusive, 'fly-on-the-wall' observations aimed to capture the spontaneous use and integration challenges of smart environments in everyday care activities, noting how often and why technologies were or were not used.

Additionally, a review of existing literature and grey literature helped establish a robust theoretical framework based on a modified extended UTAUT model (Venkatesh, et al. 2003), tailored specifically for the geriatric care context. This model's applicability will be in the next stage of this study empirically tested in two phases: first, through ethnographic studies within the living labs to assess real-time usage and integration, and second, via a structured survey targeting care staff to evaluate their perceptions, adoption drivers, and resistance points concerning smart care technologies.

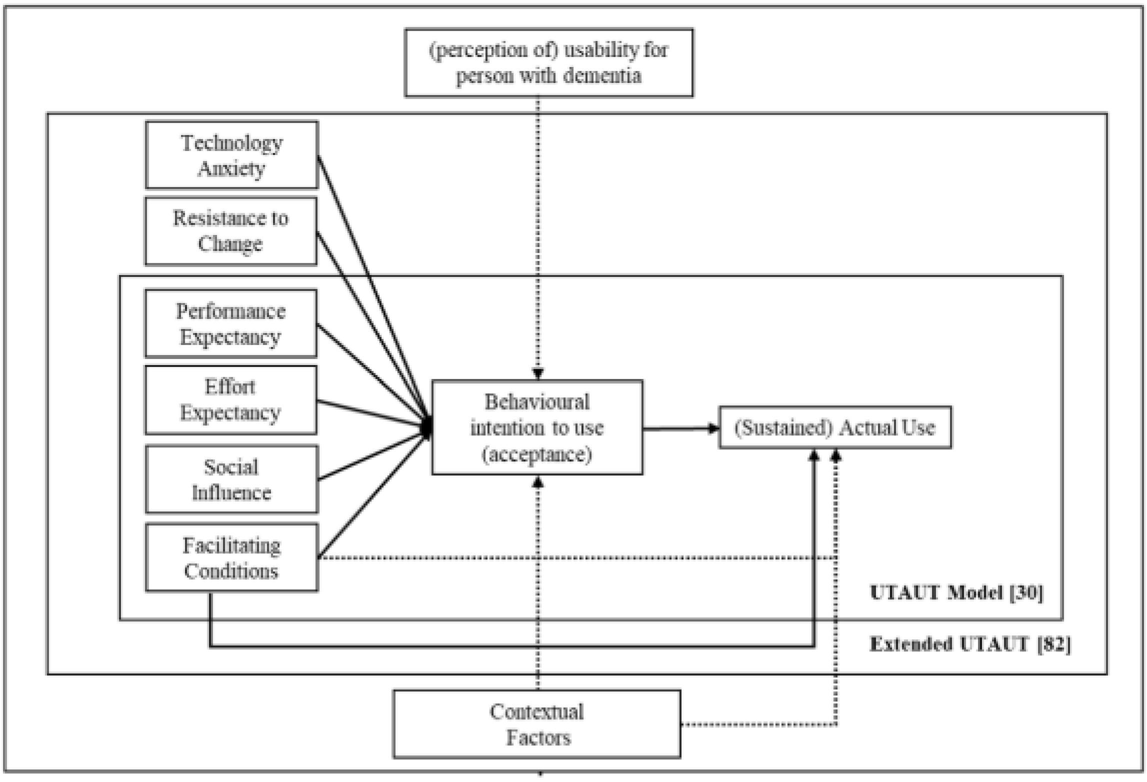


Figure 1. Theoretical framework of the study based on UTAUT

3. Results and analysis

This section presents the findings from a literature review on existing adoption models for smart environments within nursing homes, combined with empirical data gathered from workshops, interviews, and observations within the Dutch nursing home care sector. This combined approach offers deep insights into both the theoretical foundations and the practical applications of these technologies.

The research focuses on the integration of existing solutions within care institutions and investigates how these can be better integrated into the care process. Given the importance and potential of these solutions, the central question of this study is how to improve the adoption and sustained use of smart environments in nursing homes to enhance the quality of dementia care. The theoretical framework of this study focuses on the adoption and embedding process within nursing home organizations, translating factors such as technology, actors, and context into measurable variables according to the modified extended UTAUT model
(Meiland, Bouman, Sävenstedt, et al., 2012; Jamin, Luyten, Delsing, et al., 2018).

As the research addresses the embedding and use of these smart environments, the 'use' factor examined includes: (1) deliberate utilization by healthcare or welfare professionals during activities such as day-care or

therapy, and (2) potentially uncontrolled usage by installation in a common area accessible to people with dementia.

3.1 State of practice: What do we see in nursing homes?

The rise of smart interactive environments specifically aimed at people with dementia is notable in Dutch nursing home practice. This demographic requires different technology due to varied care needs, approaches, and the specific types of interactions they benefit from. It is noted that such technology is already introduced and employed across all Dutch nursing homes to enhance the care process for people with dementia (Mohammadi, 2014). Surveys conducted by the Dutch government (Ministry of Health, Welfare and Sport, NHS, 2017; Rosenberg et al., 2018) indicate that these smart environments are predominantly used to organize activities within the nursing homes, especially in communal gathering areas. To illustrate the diversity and application of these interactive environments found in Dutch nursing homes, we categorize them commonly into two main types: Interactive engagement hubs and Immersive experience zones.

- Interactive engagement hubs to encourage activities, such as:
    - Magic Table (Tovertafel): Widely adopted across over 4,000 nursing homes globally, this table is known for its interactive games that stimulate cognitive functions and encourage social interaction (Vandelanotte, et al., 2018).

  - Experience or Museum Table: Provides educational and cultural experiences through interactive displays, enhancing learning and engagement (Zhang, et al., 2014).

- <u>Immersive experience zones including</u>:
  - Interactive Paintings and Experience Spaces: Technologies like the 'Magical Interactive Painting (MIS)' and 'WINDOW' respond to residents' movements, promoting interactive and sensory engagement (Dé Dementie-winkel.nl, 2020; Health Holland, 2020).
  - BeleefTV: Offer a versatile platform for a range of interactive activities, from simple games to complex learning sessions, catering to the varied interests of residents.
  - Replicated environmental spaces: These include detailed recreations of familiar settings such as train compartments and buses or beaches designed to evoke past memories or offering comforting experiences (RTV Oost, 2019; Thuis in het verpleeghuis, 2016).

The smart environments are integral to organizing activities and enhancing interactions within nursing homes, aiming to improve the quality of life and behavioural responses among residents with dementia. A systematic literature review highlights the positive behavioural changes associated with these environments, such as increased social contact and improved sleep patterns (Mendoza, et al. 2005). However, the literature also notes a gap in evidence concerning long-term benefits on quality of life and cognitive outcomes. The integration and sustained use of these technologies pose ongoing challenges, underlining the need for continued research and adaptation to maximize their effectiveness in care settings.
Our empirical study involved the five care organizations, each equipped with one or more smart interactive environments. A recurring observation, voiced during a January 2018 workshop, was the underuse of available technology, exemplified by the comment: "we do have magic tables, but they are gathering dust" (figure 4.2). This issue highlights the challenges of embedding these technologies into daily practice, a theme echoed in reports by Ministry of Health, Welfare and Sport, which noted that "A smart device is quickly purchased, but embedding proves more difficult" (Jester Strategy, 2019). Observations across two living labs involved in this study also underline these findings. Discussions with caregivers and staff pointed to several barriers such as inadequate time for training and organizational fragmentation. In-depth interviews further identified critical hindrances to technology integration, such as the rapid adoption of functional technologies like hip airbags, contrasted with the less successful implementation of experience tables. Common obstacles included a mismatch between technological solutions and local needs, insufficient digital skills among staff, and a lack of dedicated time and resources for effective use of the technologies.

Feedback from stakeholders highlighted the inadequacy of existing models to fully address the complex needs of dementia care. The observed lack of active technology use, combined with significant technological and staff-related barriers, underscores the necessity for a more comprehensive framework. This framework should integrate both micro-environmental factors (direct user interactions) and macro-environmental elements (policy and social norms). Based on these insights, our research is now focused on refining and validating a modified UTAUT model, aimed at enhancing technology adoption and efficacy in dementia care settings. The subsequent section will detail specific intervention strategies to advance this goal. The next section specifically addresses this.

Figure 2: Examples of interactive rooms in nursing homes: left: interactive cycling combines physical activity with cognitive stimulation; right: Beach room utilizes sound, wind, warmth, and other sensory stimuli for sensory stimulation.

3.2 From observation to theory: modifying adoption models

The adoption of smart technology in the healthcare sector is influenced by various factors including technological readiness, the adaptation of care processes, and the digital competence of the staff. Barriers such as high costs, lack of technical support, and resistance to change pose significant challenges. In the context of dementia care, traditional adoption models such as the Unified Theory of Acceptance and Use of Technology (UTAUT) are often applied alongside TAM and TPB (Elwood, et al., 2013; Hoque & Sorwar, 2017; Renout, 2020). However, these models do not always provide sufficient insight into the ways adoption can be influenced (Elwood, Galante, Pickering, et al., 2013;). In response to criticism of these models, the UTAUT model has been extended to include other socio-psychological and contextual factors, termed the 'extended UTAUT model' (Qwiek, 2020). This model can predict 70% of the intention to use and 50% of actual use (Elwood, et al., 2013; Hoque & Sorwar, 2017).

The "State of Practice" observed in Dutch nursing homes, alongside insights from literature, underscores significant challenges in implementing technology for people with dementia, urging a re-evaluation of conventional technology adoption models. Given the unique needs of this target group, this study utilizes the UTAUT model to propose several factors influencing the intention and utilization of technology within the organizational care framework in nursing homes:

- **Expectancy**: This pivotal determinant of technology usage intentions is primarily influenced by anticipated outcomes. Empirical data and literature suggest that care staff recognize beneficial outcomes from smart interactive spaces, such as enhanced efficiency and time savings in care organization (Hoque & Sorwar, 2017; Ajzen, 2011). However, the extent to which technology assists in performing work more efficiently remains under-explored, serving both as a potential barrier and a stimulus for actual use (Ajzen, 2011). It is crucial to differentiate between performance expectations related to patient outcomes and the perceived value added to caregivers' daily tasks.
- **Performance expectancy**: A key factor in determining the intention to use technology is the expectation around the yield of this use. From the empirical part of this study and the literature, there are indications that care staff define useful outcomes of smart interactive spaces including the potential for mor efficiency and timesaving in organization of care (Hoque & Sorwar, 2017; Ajzen, 2011). However, whether the technology will assist in (more efficiently) performing the work is less researched and could be both a barrier and a stimulus for actual use (Ajzen, 2011). This factor must therefore distinguish between performance expectancy regarding outcomes for the person with dementia and added value for the daily work of the caregivers.
- **Social influence**: This concerns the pressure from the (work and the end user) environment on attitude and use. In this case, it will mainly be about what the care or welfare worker thinks is socially desirable, for example, because the organization in which they work wants to focus on 'experience-oriented care' (Holthe, et al., 2018).
- **Facilitating conditions**: This refers to the embedding in social, techno-spatial, and organizational infrastructure, which can facilitate the use and acceptance of a particular technology. In the context of smart environments, this concerns organizational factors such as 'innovation readiness' (Elwood, et al., 2013; Dai, et al., 2020; Holthe, et al., 2018), a vision on these innovations from the organization or supportive management. Organizations are not always 'implementation-ready' following an effectiveness study, because organizational factors are often not well embedded (Aldrich, 2003). In addition, the technospatial context is important: unlike 'boxed technology' (i.e., portable technology), smart interactive environments are much more closely bound to the place where they are installed and remain to be part of the daily experience for a longer period. The place where this is done in relation to, among other things, (day)light, walking routes, and common areas is relevant for (the intention to) use these spaces.
- **Technology anxiety and resistance to change**: In nursing homes, technology anxiety can significantly delay the adoption and effective utilization of care technologies. This anxiety

often arises from concerns over the complexities of operating new technologies, reduced self-efficacy, and uncertainties of potential job displacement. These factors can significantly reduce both the willingness and actual usage of these environments, despite their potential benefits in enhancing care quality and efficiency. Moreover, resistance to change is a crucial factor, as alterations in traditional practices within care organizations can induce uncertainty and reluctance among staff, further obstructing the integration of new technologies (Hoque & Sorwar, 2017; Li, et al., 2020; Pal, et al., 2019; Chen, et al., 2020).

- Dynamic in dementia care: An important factor from research around the design of smart places for people with dementia and a recurring theme in this study, is the extent to which such environment can be used (independently) by the person with dementia. The dual nature of nursing homes as both living and workspaces necessitates careful consideration of how technology is adopted and utilized. This involves both the perception of caregivers and perception and capabilities of the older people with dementia of the use of the space (Health Holland, 2020; IDé, 2008). The ease of use of smart spaces significantly impacts both care staff and residents with dementia. The effectiveness of these technologies on dementia-related health outcomes hinges on successful, sustainable implementation under specific, conducive conditions. Studies indicate that technology's user-friendliness increases intention to use it, highlighting the importance of technological and organizational facilitation (Elwood, Galante, Pickering, et al., 2013; Dai, et al., 2020; Cohene, et al., 2007). Moreover, the actual usage by persons with dementia is critically dependent on these factors, as well as the alignment of the technologies with the daily routines and physical layouts of the nursing homes. The technological and spatial context must support easy access and navigability for dementia patients, integrating these systems into common areas and considering elements like daylight and walking routes to enhance engagement and usability.
- Contextual Factors: Study shows that various contextual factors influence the intention and use of technology (Grave & Mohammadi, 2018; Dai, et al., 2020; Hammink, Moor, & Mohammadi, 2021). In addition to the impact of the fairly recent health crisis around Covid-19, the effect of legislation and policy changes on adoption processes has proven very relevant in the past. In the current healthcare climate in the Netherlands, this includes the shortage of care personnel and the focus of political policy on ageing-in-place as long as possible (Renout, 2021; Nagasawa, 2020; Seifert, Cotten, & Xie, 2020). These contextual factors are a reason to not only include the processes and people within the nursing homes ('facilitating conditions'), but also external factors that affect the nursing homes, staff, or people with dementia.

4. Discussion and conclusion

The deployment of smart environments within nursing homes for individuals with dementia represents a transformative step in contextualizing technology within these dual-purpose settings. Through the integration of AI, sensor technology, and context-aware systems, these environments dynamically adjust to real-time data, enhancing daily living conditions for residents. Such adjustments aim to stimulate positive behavioral changes and improve overall quality of life, marking a shift towards the domestication of technology where its presence becomes an integrated, less conspicuous part of the care environment. This shift introduces technology as an integrated, less conspicuous part of the care environment, fostering a sense of normalcy and belonging. This subtle integration allows residents and staff to gradually acclimate to the technology's presence, fostering a sense of familiarity and acceptance. The complexity of nursing homes serving both as living environments for residents and workspaces for caregivers adds to the criticality of the domestication process. Here, technology must blend seamlessly into the everyday life to support a homelike atmosphere and efficient care practices, making its assimilation into daily routines crucial for pervasive acceptance.

This integration reflects a broader trend towards more integrated, technology-enhanced environments that support both residents and caregivers, moving away from traditional care models. It ensures that smart environments become an integral, unobtrusive part of the care setting, essential for the acceptance and effective use of these technologies in enhancing care quality.

However, the sustained use in practice and long-term effectiveness of these technologies face significant hurdles. This challenge underscores the necessity of a better understanding of mechanisms and refining existing theoretical models such as the UTAUT model to better account for the specific challenges in caring for people with dementia and the broader organizational and policy context in which this care occurs.

Technologies must be implemented in a manner that respects the sensitive nature of the care process and the dignity of all residents, safeguarding their personal and sensitive information and ensuring that their involvement is always respectful and consensual. The effectiveness of technological interventions in nursing homes is highly dependent on the variability of responses from the target group, which includes both residents with dementia and their caregivers. The digital competence of caregivers also varies widely, which can lead to inconsistencies in how technology is adopted and used across different settings. It is crucial that technological solutions enhance rather than replace human interactions, emphasizing the support of meaningful connections between caregivers and residents.

Resistance to new technologies within care organizations often arises from deep-seated routines and established cultural norms. Introducing new technologies can disrupt these practices, requiring careful planning and sensitization to ease the transition. Furthermore, effective caregiver training is crucial for adopting and using new technologies efficiently, though it can be costly and time-consuming and may encounter resistance due to the change it represents.

The success of technological implementations in dementia care also hinges on the socio-spatial context. This involves integrating technologies within the physical and social environments of nursing homes in a way that aligns with the existing structures and routines. The design of the space, accessibility of technology for all residents, and harmony with ongoing social activities play crucial roles in how well these technologies are accepted and integrated into daily operations.

Expectations regarding the performance of technology and the perceived effort required to use it effectively (performance expectancy and effort expectancy) are pivotal in shaping acceptance and ongoing utilization. A negative perception or daunting expectations about technology's usability can significantly hinder its adoption. Proactive training and ongoing support are essential to mitigate anxieties and enhance familiarity with digital tools among care staff, fostering a supportive environment for technology adoption.

By improving understanding of the operational, technological, and human factors influencing the integration of smart environments, care institutions can develop more effective and user-centric care solutions. This requires ongoing evaluation and adjustment of technologies to ensure they not only meet technical requirements but also achieve pervasive acceptance and effective use in daily care practices.

While the deployment of smart environments within nursing homes offers substantial benefits in enhancing the quality of life for people with dementia, achieving these outcomes depends critically on the technologies' ability to integrate seamlessly into the socio-spatial fabric of the care setting. Future research should continue to explore and refine the models of adoption and integration, focusing on the long-term impacts and practical implementation strategies that respect both the technological and human aspects of dementia care. It is through such comprehensive and ongoing efforts that smart environments can truly fulfill their potential, supporting the daily lives of those with dementia and the professionals who care for them.

While this study provides initial insights into the conditions for the adoption and sustained use of smart environments within specific Dutch dementia care settings involved in this research, the findings are constrained to these particular organizations and may not be indicative of broader trends. Given the exploratory nature of this work, it highlights the necessity for ongoing research to deepen the understanding of implementation dynamics and mechanisms and to generalize these findings to other care settings both within and beyond the Netherlands.

Acknowledgements

This study was funded by the Dutch Research Council (NWO) within the framework of the Taskforce for Applied Research SIA RAAK-PRO program. We are grateful for the collaboration with various knowledge institutions and the five mentioned care organisations, which have been essential for making this study possible.

References

Alzheimer Nederland. (2017). Cijfers en Feiten over Dementie. Retrieved from https://www.alzheimer-nederland.nl/sites/default/files/directupload/factsheet-dementiealgemeen.pdf

Alzheimer's Disease International. (2015). Dementia statistics. Retrieved from https://www.alz.co.uk/research/statistics

Huijsman, R. (2019). Onder Dementieprofessoren. Alzheimer Nederland en Vilans. Retrieved from https://www.vilans.nl/vilans/media/images/producten/boekje-onder-dementieprofessoren.pdf

NHS. (2017). Is there a cure for dementia?. Retrieved from https://www.nhs.uk/conditions/dementia/cure/

Servick, K. (2019). Another major drug candidate targeting the brain plaques of Alzheimer's disease has failed. What's left? Science | AAAS. Retrieved from

https://www.sciencemag.org/news/2019/03/another-major-drug-candidate-targeting-brainplaques-alzheimer-s-disease-has-failed

Francke, A., van der Heide, I., de Bruin, S., et al. (2018). Een samenhangend beeld van dementie en dementiezorg: kerncijfers, behoeften, aanbod en impact. Themarapportage van de Staat van Volksgezondheid en Zorg. Nivel. Retrieved from www.nivel.nl

Hamers, K., Hammink, C., Mohammadi, M. (2018). Empowering Encounters: An exploration of smart environments for stimulating encounters for older adults with dementia in inpatient facilities. In Temeljotov Salaj, A., Veuger, J., Bartels, D., et al. (Eds.), 3rd CONFERENCE OF INTERDISCIPLINARY RESEARCH ON REAL ESTATE (pp. 276–292). Ljubljana: Institute of Real Estate Studies.

Huber, M., van Vliet, M., Giezenberg, M., et al. (2016). Towards a 'patient-centred' operationalization of the new dynamic concept of health: a mixed methods study. BMJ open, 6, e010091.

Campo, M., & Chaudhury, H. (2012). Informal social interaction among residents with dementia in special care units: Exploring the role of the physical and social environments. Dementia, 11, 401–423.

Elwood P, Galante J, Pickering J, et al. Healthy Lifestyles Reduce the Incidence of Chronic Diseases and Dementia: Evidence from the Caerphilly Cohort Study. Sathian K, editor. PLoS ONE. 2013;8:e81877.

Marquardt, G., Bueter, K., & Motzek, T. (2014). Impact of the Design of the Built Environment on People with Dementia: An Evidence-Based Review. HERD: Health Environments Research & Design Journal, 8, 127–157.

Prins, M., Heijkants, C., & Willemse, B. (2018). Onbegrepen gedrag in de verpleeghuiszorg voor mensen met dementie. Gedrag & Organisatie, 31(1), 34-58.

Mohammadi, M. (2014). Domoticakompas: inzichten uit een decennium slimme zorgprojecten in Nederland. Eindhoven: Van Litsenburg B.V.

Ferreira, A.R., Dias, C.C., & Fernandes, L. (2016). Needs in Nursing Homes and Their Relation with Cognitive and Functional Decline, Behavioral and Psychological Symptoms. Frontiers in Aging Neuroscience, 8, 72. DOI:10.3389/fnagi.2016.00072

Mohammadi, M. (2020). Smart Technology and Design for Healthy Ageing. Amsterdam: Amsterdam University of Applied Sciences.

Mohammadi, M., Goossens, R., & Verheij, L. (2021). E-Health Services for People with Dementia: A Smart Living Lab Study. Journal of Medical Internet Research, 23, e26688.

Pal, A., De', R., Herath, T., et al. (2019). A review of contextual factors affecting mobile payment adoption and use. Journal of Banking and Financial Technology, 3, 43–57.

Chen, A. T., Ge, S., Cho, S., et al. (2020). Reactions to COVID-19, information and technology use, and social connectedness among older adults with pre-frailty and frailty. Geriatric Nursing. Available from:

http://www.sciencedirect.com/science/article/pii/S0197457220302457.

IDé. (2008). Rust en afleiding vinden in de trein, zonder erop uit te hoeven. Innovatiekring Dementie - IDé. Available from: https://www.innovatiekringdementie.nl/.

Renout, F. (2021). Fransen in de rij voor Nederlandse 'dementie-games'. AD.nl. Available from: https://www.ad.nl/buitenland/fransen-in-de-rij-voor-nederlandse-dementie-games~af2fcabb/.

Li, C., Kang, K., Lin, X., et al. (2020). Promoting Older Residents' Social Interaction and Wellbeing: A Design Perspective. Sustainability, 12, 2834.

Holthe, T., Halvorsrud, L., Karterud, D., et al. (2018). Usability and acceptability of technology for community-dwelling older adults with mild cognitive impairment and dementia: a systematic literature review. Clinical Interventions in Aging, 13, 863–886.

Aldrich, F. K. (2003). Smart Homes: Past, Present, and Future. In R. Harper (Ed.), Inside the Smart Home(pp. 17–39). London: Springer-Verlag. Available from: http://link.springer.com/10.1007/1-85233-854- 7_2.

Cohene, T., Baecker, R., Marziali, E., et al. (2007). Memories of a life: a design case study for Alzheimer's disease. Universal Usability, John Wiley & Sons, 357–387.

NHS. (2017). Is there a cure for dementia? Retrieved August 15, 2019, from https://www.nhs.uk/conditions/dementia/cure/

Rosenberg, A., Ngandu, T., Rusanen, M., et al. (2018). Multidomain lifestyle intervention benefits a large elderly population at risk for cognitive decline and dementia regardless of baseline characteristics: The FINGER trial. Alzheimer's & Dementia, 14(3), 263-270.

Vandelanotte, C., Duncan, M. J., Maher, C. A., et al. (2018). The effectiveness of a web-based computer-tailored physical activity intervention using Fitbit activity trackers: Randomized trial. Journal of Medical Internet Research, 20(12), e11321. https://doi.org/10.2196/11321

Zhang, Q., Su, Y., & Yu, P. (2014). Assisting an elderly with early dementia using wireless sensors data in smarter safer home. In Proceedings of the International Conference on Informatics and Semiotics in Organisations (pp. 398-404). Springer.

Dé Dementie-winkel.nl. (2020). Persoonlijke interactieve muur - PIM. Retrieved December 13, 2020, from https://www.dementie-winkel.nl/persoonlijke-interactieve-muur-PIM

Health Holland. (2020). Kennis- en Innovatieagenda 2020-2023. Retrieved October 13, 2020, from https://www.health-holland.com/sites/default/files/downloads/kennis-en-innovatieagenda-2020- 2023-gezondheid-en-zorg_0.pdf.

4 Smart homes & inclusive communities: **Conference paper**

Implement Virtual Reality, Digital Twin, and Artificial Intelligence in the Social Housing Renovation Project Based on the Blue Zones Concept

Chuan Ma[1]*, Peyman Najafi[1], Olivia Guerra-Santin[1], Masi Mohammadi[1]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Chuan Ma (c.ma@tue.nl)

Abstract: 'Blue Zones' is the region with the highest concentration and longevity of older adults globally, and the living environment there may provide some design inspiration to support healthy ageing. The main purpose of this study is to investigate stakeholders' acceptance of the digital twin models based on the Blue Zones concept presented by virtual reality. The main participants were designers and clients involved in the renovation project of the Malvalaan community in the Netherlands. In our study, we identified clients' requirements for housing renovation through interviews, established a digital twin model of the residential compound, and used AI-aided design to create healthy ageing scenarios. We used architectural drawings and virtual reality devices to show the environmental changes before and after the renovation. Although participants had different attitudes toward the Blue Zones concept, they preferred design schemes to be presented using virtual reality technologies. Future research is suggested to gain more insight into longevity regions and use the knowledge to create age-friendly environments for older adults.

Keywords: architectural design, virtual reality, digital twin, artificial intelligence, housing renovation

1. Introduction

The term 'Blue Zones' (BZs) originates from demographic research conducted nearly twenty years ago. It identifies regions worldwide where people live significantly longer. There are five BZs, including Sardinia (Italy), Okinawa (Japan), Nicoya Peninsula (Costa Rica), Ikaria (Greece), and Loma Linda (United States) (Bendjilali et al., 2014; Buettner & Skemp, 2016; Madrigal-Leer et al., 2020; Poulain et al., 2004, 2021; Willcox et al., 2006). The key characteristics of these regions, including strong community bonds, accessible and inclusive environments, and lifestyle patterns conducive to age well, provide valuable inspirations for renovation design, which offers new perspectives to designing environments that promote longevity and well-being (Marston et al., 2021). By applying the knowledge of BZs, the existing housing stock can evolve beyond mere architectural upgrades to become holistic living spaces supporting older adults' physical, mental, and social health. For the neighbourhood scale, the current BZs could be the reference for transforming the community through environmental changes, bridging the connections between indoor spaces and nature, and fostering a sense of belonging among residents (Lakshmanan et al., 2020). All in all, BZs provide age-friendly features of the built environment that meet physical needs and nurture residents' mental and social health.

The integration of advanced technologies such as virtual reality (VR) and digital twin (DT) with traditional architectural principles has been increasingly used in design studies and practices, particularly on urban and neighbourhood scales (Najafi et al., 2021). However, the advent of VR and DT presents a ground-breaking opportunity in architectural design. VR allows stakeholders and end-users (e.g. architects, engineers and decision-makers) to immerse themselves in the envisioned environment before construction begins, facilitating a deeper understanding and engagement with the proposed changes. This immersive experience could demonstrate spatial relationships, material finishes, and overall design aesthetics, facilitating more informed decision-making and client satisfaction (Koutsabasis et al., 2012). The technology application enables the collaboration between designers and clients, ensuring that the result aligns more closely with clients' needs and preferences. Current VR applications in architectural design have shown that VR can be utilised for many purposes, such as design evaluation (Koutsabasis et al., 2012; Ma et al., 2022). DT creates dynamic, real-time digital replicas of physical spaces. It can be used instrumentally in monitoring and analysing the performance of housing projects, allowing for continuous improvement and adaptation based on actual usage patterns and environmental factors (Yao et al., 2023). DT is often applied for building construction and maintenance with data exchange but rarely for design purposes. Artificial intelligence (AI) is increasingly used in architectural design to enhance efficiency, creativity, and sustainability (Bölek et al., 2023). AI tools can help architects generate multiple design options, 3D models, and renderings to create stunning visual effects and realistic simulations, potentially supercharging the design process and making it more efficient and collaborative.

With the development of VR, DT, and AI, architectural design approaches need to be changed in an efficient, scientific, and human-centred way (Vite et al., 2021). This study explores the innovative intersection of these technologies with the BZs concept in the context of social housing renovation projects. Although the process follows traditional architectural design steps: investigating user requirements, proposing design strategies according to requirements, 3D modelling, and final presentation to stakeholders, the innovation is how to apply these techniques to design, modelling, and presentation. The study will investigate the stakeholders' acceptance, especially the senior residents, of experiencing the renovation design based on the BZs concept using VR.

2. Methods

2.1 Research design

The study process is shown in Figure 1. The clients (senior residents) were involved in data collection and the VR experiment phases. In particular, the VR experiment focused on 'communication', which describes the exchange of information between participants experiencing the immersive environments in DT. The participants were: 1) five designers (one of them is a consultant from the housing association); 2) five clients (senior residents over 65 years old) willing to participate in the renovation design and use VR devices. They were invited to the study through an ethically approved recruitment process.

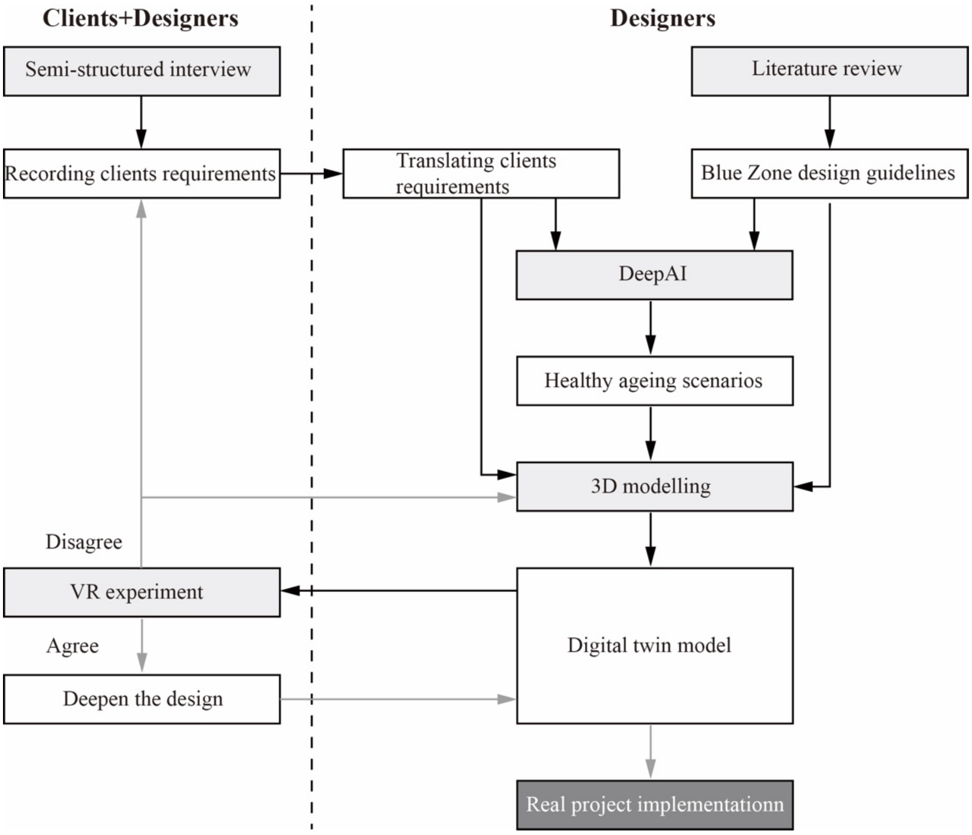


Figure 1. The workflow of the study.

2.2 Case study

Figure 2. The Malvalaan community before renovation.

The case study is in Malvalaan, the Netherlands. Currently, the community consists of three apartment buildings (Figure 2) where most residents live independently (One apartment building on the west side was demolished in 2021, and a new care centre is planned to be built on the same site). There are two apartment types for each floor (one living room and one bedroom for single persons; one living room and two bedrooms for couples), oriented east or west. The balcony of each apartment could be slightly different according to its position (Figure 3). The apartment buildings were built in the 1970s and are connected by glass corridors. Although the outdoor common spaces are designed with barrier-free design guidelines and the greenery rate is high, the building facilities are still old, which influences residents' living qualities.

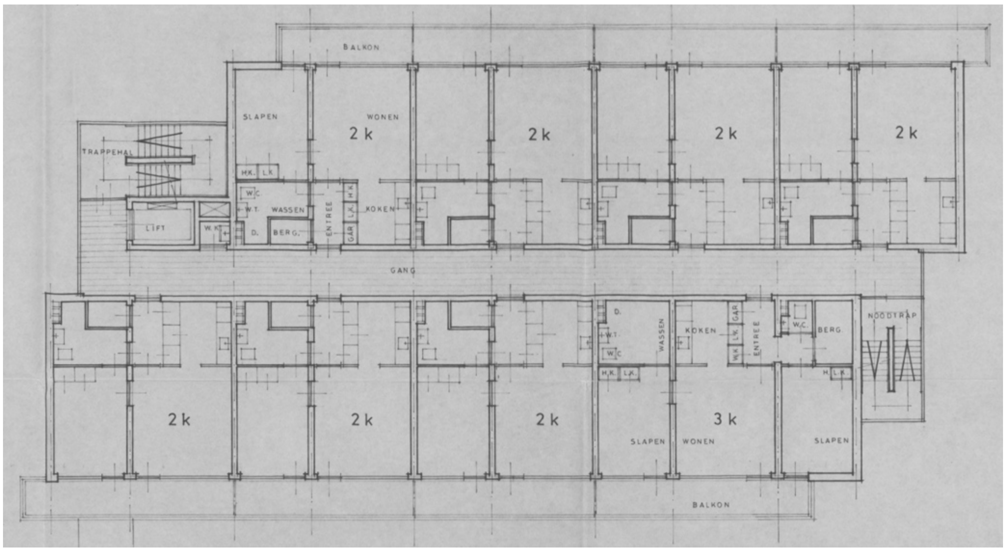


Figure 3. The floor plan of the apartment buildings (source: ARCHITEKTENBURO VAN DE KERKHOF).

2.3 Data collection and translation

The study started with a literature review and semi-structured interviews with five clients living in Malvalaan. Through the literature review, we searched the existing research focusing on the BZs concept at the architectural design level. The Keywords include: 'blue zone' and 'architecture' or 'building' or 'dwelling' and 'design' or 'guideline' or 'principle'. The knowledge of describing building characteristics and design features of BZs was screened and summarised.

Five clients, with an average age of 72.8, living in the studied community, participated in the research. They were invited to conduct semi-structured interviews in May 2023. During the interview, they described and showed their current living conditions, problems encountered, and the requirements for upcoming renovation from five main aspects: demographic information (e.g. how long do you live in Malvalaan), living environmental quality (e.g. how do you keep the natural ventilation in winter), daily activity (e.g. how you prepare a shower), space usage (e.g. how would like to change the room layout), and social connection (e.g. what do you do if in the emergency). The interview transcriptions were coded for thematic analysis, and each aspect was categorised by problems/hazards of the current living environment or expectations for renovation.

2.4 Scenario generation process

AI was employed in the renovation design process to conceptualise the BZs. We used pictures taken from interviews as base maps for AI generation. Detailed prompts based on the building characteristics and design features summarised from the literature review were employed in the AI image generator to produce images. Following the AI's generation of initial imagery, the images were then enhanced in Photoshop, adding more details and furniture. This was done to refine the visuals further and imbue the designs with greater depth and specificity to enhance the sensory perception of space through AI and human collaboration. The final designs emerged as a blend of AI application and human aesthetic judgment, intended to depict physical spaces and promote realism. This approach facilitates the rapid generation and testing of diverse design layouts and material choices, optimising the design process through efficient concept image generation. Due to the limited documents, descriptions, and complexity of the BZs, AI tools were utilised to 'describe the living environments in BZs' based on big data to support the creation of 3D models.

2.5 Malvalaan DT modelling

We used three 3D and BIM modelling software platforms (SketchUp, Blender, and Revit). The model information and details were based on the architectural drawings from the architectural firm and photographic documentation of the sites. The three existing residential buildings, corridors, the community's landscaped features (e.g. slopes, pathways, trees, and benches), and adjacent streets were built according to the current situation. This virtual milieu was crafted to evoke a sense of familiarity amongst stakeholders. Emphasis was placed on accurately replicating the domiciles of clients, encompassing spatial configurations, furnishings, and textural details, to facilitate comparative evaluation. Renovation scenarios were created based on the current settings of each apartment, AI-generated images, and the specific requirements of each client. We also considered their health conditions, habits, and future lifestyles during the design phase. The VR animations were engineered using the Unity gaming engine, with the Meta Oculus Quest II envisioned as an interactive and customisable tool for urban and architectural exploration. Recent studies suggest that game engines, such as Unity and Unreal Engine, offer a heightened degree of interoperability in VR and provide cave automatic virtual environments with human-computer-interaction workflows, enabling the creation of interactive and immersive experiences. These engines also offer features such as real-time lighting and shadow effects, various camera angles and perspectives, and the ability to incorporate sound and other sensory elements (Deng et al., 2021; White et al., 2021). This model synchronises the environmental data (e.g. weather) with the outside world.

2.6 VR experiment

Figure 4. The participants in the VR experiment.

Five interviewed clients and five designers were invited to evaluate the proposed renovation designs. The VR experiment and data collection were conducted in the activity room in the Malvalaan community in December 2023. The researchers presented the renovation design concept to participants using architectural drawings and collected feedback on the BZs through questionnaires. Then, the participants were invited to use VR headsets to view the renovation design of selected scenarios (own home or others). The experiments for each participant took approximately 10 minutes, starting at the entrance of the building and ending at their apartments. Considering that the VR controllers could be complicated for older adults and the furniture in the room restricted the walking area, we designed a sitting mode for participants and helped them navigate the scenarios. We prepared a screen to show what people saw in VR headsets so all participants could freely share ideas and comments, such as which areas in the renovated rooms they liked or disliked. Subsequently, the qualitative data from these sessions were subjected to thematic analysis, a methodological approach to identify, analyse, and report patterns (themes) within the data. After using VR, they completed the questionnaires on VR experiences.

3. Results

A BZs checklist provided by (Marston et al., 2021) offers individuals a tool to understand their home environment and guidance for improvement. Based on the checklist and the interview transcriptions, Table 1 lists the feasible design strategies in each area: 1) Living room, 2) Kitchen, 4) Bedroom, and 4) Bathroom. Most checklist items are specific, such as 'place a longevity food list on the refrigerator' and 'use a walk-in shower stall', which can be used directly as a prompt for AI tools. The items, such as 'create a destination room/space for tranquillity and relaxation', need to take into account the daily life of older adults and the space usage to reword the prompt as 'wooden furniture in the living room is placed against the wall, only a wooden tea table and cushion are in the middle'.

Table 1. The description of the BZs interior design (selected for AI prompt) (Marston et al., 2021).

Living room	Kitchen	Bedroom	Bathroom
• Create a destination room/space for tranquillity and relaxation. • Design a clear space for exercising. • Decorate the room with plants.	• Dedicate the top shelves with ornaments, plants, or food. • Add just the dining area and furniture for older adults. • Add design and detail that enhances appetite (e.g. a longevity food list on the refrigerator).	• Use sun-shading elements on windows. • Design the bedroom with natural elements. • Improve the building insulation. • Install monitoring devices at the bedside.	• Reinstall facilities and switches at proper heights. • Design a space for laundry. • Use a walk-in shower stall.

AI image generator (DeepAI) was used to generate the virtual rendering according to the BZs concept. Figure 5 is an example of images of reality (top), AI-generated (middle), and rendering in Unity Engine (bottom). The AI image was based on the prompts from Table 1 and pictures or descriptions of the Malvalaan residential buildings (e.g. 'Dutch old apartment', 'the balcony outside the living room', and 'wooden floor'). Although the AI images do not show the real scenes, they can be inspirations for designers who have not been to the BZs. Based on these images and the BIM model of the participants' apartments, we created renovated scenarios based on each room's layout, textures, furniture, and ornaments. The details referenced the AI images, such as the stickers on the fridge and room arrangements. Moreover, the 3D model layouts and textures, such as the TV set and furniture, were closer to reality. However, due to the hardware limitation and ensuring fluency in the VR environment, the rendering of model quality was not very high.

Figure 5. The picture was taken in the participant’s home (top), AI-generated image (middle), and DT model (bottom).

VR technology lowered the threshold for participants to become engaged in the housing renovation design process, as no detailed technical knowledge is needed. Participants can discuss the scenarios, preferences, and problems when experiencing the immersive environment. The experiment provided clients access to what their homes will look like in the future, as the renovation can take years to complete. It allowed any complaints to be heard before the building began construction. Figure 6 shows the questionnaire results from the participants. They were asked to rate the design expression clarity, design process engagement, home environment improvement, renovation plan acceptance, and overall satisfaction with the design presentation. Comparing the architectural drawings, the design expression clarity, process engagement, and overall satisfaction significantly increased using VR (red colour in Figure 6). According to the discussion, participants, especially the client, were quite surprised with the tailored interior design based on personal belongings. They said, 'Yes, the furniture looks like my stuff' and 'That is understandable for me because the room is familiar and personal.' They also discovered if some iconic objects were displayed somewhere in models. However, the participants still had different attitudes toward the renovated environments they saw in VR, and nearly half disagreed with some design concepts based on BZs. The clients care more about spatial usability and their own situations, such as the discussions during the experimentation, 'I will never use the new destination room and do not think it helps keep longevity', 'I need storage space near the entrance', and 'I do not often cook, so I do not need a beautiful and greenery kitchen'. The designers also noticed the problems of space usefulness when they were in immersive environments and communicated with clients. This can provide designers with useful insight into the rationality of implementing design concepts in different regions and cultures.

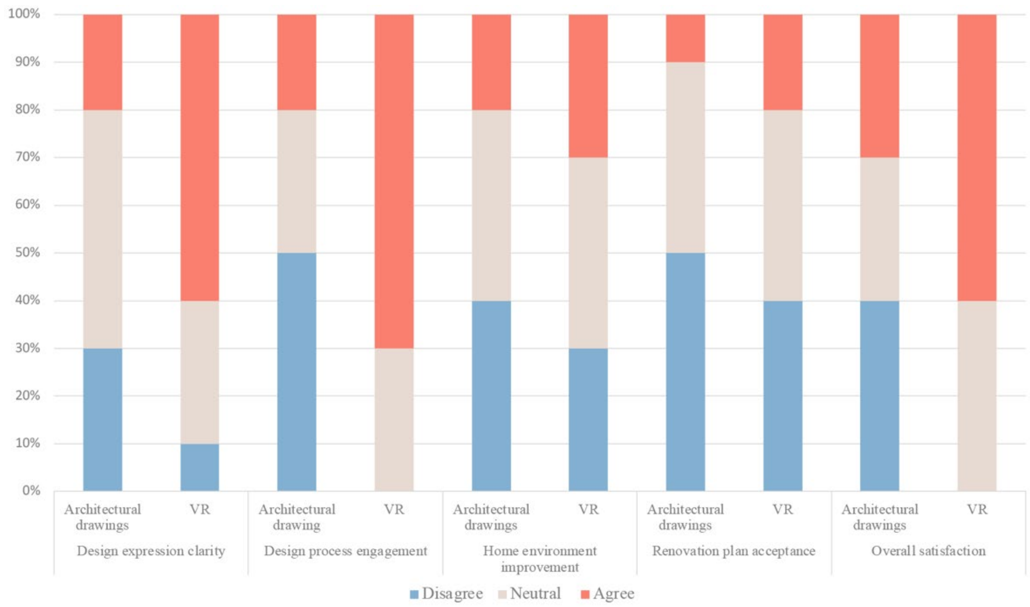


Figure 6. The questionnaire results of architectural drawings and VR presentation.

4. Discussion

This study explored implementing the BZs concept in the social housing renovation project using VR, DT, and AI. We developed customisable models for clients, which limited the number of participants in this research. Designers and clients reviewed and evaluated the renovation scenarios presented in immersive environments by VR devices. Considering that offering the conceptual design was the most critical phase of the design process, we used innovative methods to lower the threshold for older adults to participate in this phase (Cross, 2000). In this study, we found that the communication of the collaborative experiment process was interesting for all stakeholders and yielded constructive comments. Although there was a lack of statistical evidence, the VR experience was quite engaging and could be an effective tool in the experimentation for participants (Koutsabasis et al., 2012). AI adds value to architectural design and inspires. DT was indispensable for modelling and data interaction in the real and virtual worlds. These technologies present a meaningful, valuable, and affordable approach to co-create better age-friendly interior spaces for the studied community (Mobach, 2008). Compared to architectural drawings, VR can help users gain a deeper understanding of the possible effects of renovation. Due to the existing literature providing limited descriptions of residential building characteristics of BZs, the output generated by AI tools and the BZs-based scenarios might not accurately present the improvement of living qualities after the renovation. Some guidelines, such as designing the room with natural elements, do not present the speciality of the BZs. Integrating indoor spaces and nature was beneficial to health, which has also been proved by different research fields (Zhong et al., 2022, 2023). Not all clients agreed with the BZs scenarios, but the actual demands they expressed, according to the VR experience, provided references and direction for designers to improve.

More theoretical underpinnings of the BZs research are needed to provide scientific guidelines for implementing healthy ageing practices. Given the healthy ageing narrative, the concept of incorporating a life course perspective for residents within the BZs who live in other countries is needed to fully gauge the factors of longevity (Editorial, 2007; Kreouzi et al., 2022). Additionally, due to the complexity of environmental effects on health and longevity, researchers and designers need to complement data, including indoor environmental parameters, building layout, and daily activity. Access to demographic information, physical ability, and other factors play essential roles in fully understanding one's personal and environmental circumstances. Thus, considering the variety of environments in which individuals live is critical for an inclusive approach (Marston et al., 2021). Exploring elements of healthy ageing from the BZs can assist their iterations and contribute to the ageing society.

5. Conclusion

In conclusion, integrating VR, DT, and AI in the design process, particularly within the social housing renovation project guided by the BZs concept, is a practical exploration. The synergy of these innovative technologies contributes to visualising the design concept and improving communications between clients and designers. The renovation scenarios were currently not well accepted because there was no adequate BZs knowledge to guide creating longevity environments. However, the immersive environments shaping 3D architectural spaces, components, and decorations offer more understandable effects than architectural drawings. This study underscores the importance of harmonising innovative technologies to provide more age-friendly design tools for the ageing population.

Acknowledgements

We appreciate the understanding and support of Malvalaan residents. We also thank our colleagues and DEEL for their direct and indirect contributions to this paper.

References

Bendjilali, N., Hsueh, W. C., He, Q., Willcox, D. C., Nievergelt, C. M., Donlon, T. A., ... Willcox, B. J. (2014). Who are the Okinawans? Ancestry, genome diversity, and implications for the genetic study of human longevity from a geographically isolated population. Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 69(12), 1474–1484. https://doi.org/10.1093/gerona/glt203

Bölek, B., Tutal, O., and Özbaşaran, H. (2023). A systematic review on artificial intelligence applications in architecture. Journal of Design for Resilience in Architecture and Planning, 4(1), 91–104. https://doi.org/10.47818/drarch.2023.v4i1085

Buettner, D., and Skemp, S. (2016). Blue Zones: Lessons From the World's Longest Lived. American Journal of Lifestyle Medicine, 10(5), 318–321. https://doi.org/10.1177/1559827616637066

Cross, N. (2000). Engineering Design Methods: Strategies for Product Design. Wiley. Retrieved from https://books.google.nl/books?id=pnhRAAAAMAAJ

Deng, T., Zhang, K., and Shen, Z. J. (Max). (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. Journal of Management Science and Engineering, 6(2), 125–134. https://doi.org/10.1016/j.jmse.2021.03.003

Editorial, G. (2007). Guest Editorial A Life Course Approach to Healthy Aging , Frailty , and Capability, 62(7), 717–721.

Koutsabasis, P., Vosinakis, S., Malisova, K., and Paparounas, N. (2012). On the value of Virtual Worlds for collaborative design. Design Studies, 33(4), 357–390. https://doi.org/10.1016/j.destud.2011.11.004

Kreouzi, M., Theodorakis, N., and Constantinou, C. (2022). Lessons Learned From Blue Zones, Lifestyle Medicine Pillars and Beyond: An Update on the Contributions of Behavior and Genetics to Wellbeing and Longevity. American Journal of Lifestyle Medicine, 0(0), 1–16. https://doi.org/10.1177/15598276221118494

Lakshmanan, S., Kinninger, A., Golub, I., Dahal, S., Birudaraju, D., Ahmad, K., ... Budoff, M. J. (2020). 20-Year trend of high prevalence of zero coronary artery calcium in beach cities of

Southern California: A blue zone? American Journal of Preventive Cardiology, 4(August), 100098. https://doi.org/10.1016/j.ajpc.2020.100098

Ma, C., Guerra-Santin, O., and Mohammadi, M. (2022). Smart home modification design strategies for ageing in place: a systematic review. Journal of Housing and the Built Environment, 37(2), 625–651. https://doi.org/10.1007/s10901-021-09888-z

Madrigal-Leer, F., Martìnez-Montandòn, A., Solìs-Umaña, M., Helo-Guzmàn, F., Alfaro-Salas, K., Barrientos-Calvo, I., … Morales-Martìnez, F. (2020). Clinical, functional, mental and social profile of the Nicoya Peninsula centenarians, Costa Rica, 2017. Aging Clinical and Experimental Research, 32(2), 313–321. https://doi.org/10.1007/s40520-019-01176-9

Marston, H. R., Niles-Yokum, K., and Silva, P. A. (2021). A commentary on blue zones®: A critical review of age-friendly environments in the 21st century and beyond. International Journal of Environmental Research and Public Health, 18(2), 1–39. https://doi.org/10.3390/ijerph18020837

Mobach, M. P. (2008). Do virtual worlds create better real worlds? Virtual Reality, 12(3), 163–179. https://doi.org/10.1007/s10055-008-0081-2

Najafi, P., Mohammadi, M., Le Blanc, P. M., and Van Wesemael, P. (2021). Experimenting a Healthy Ageing Community in Immersive Virtual Reality Environment: The Case of World's Longest-lived Populations. 2021 17th International Conference on Intelligent Environments, IE 2021 - Proceedings. https://doi.org/10.1109/IE51775.2021.9486595

Poulain, M., Herm, A., Errigo, A., Chrysohoou, C., Legrand, R., Passarino, G., … Pes, G. M. (2021). Specific features of the oldest old from the Longevity Blue Zones in Ikaria and Sardinia. Mechanisms of Ageing and Development, 198(July), 111543. https://doi.org/10.1016/j.mad.2021.111543

Poulain, M., Pes, G. M., Grasland, C., Carru, C., Ferrucci, L., Baggio, G., … Deiana, L. (2004). Identification of a geographic area characterized by extreme longevity in the Sardinia island: The AKEA study. Experimental Gerontology, 39(9), 1423–1429. https://doi.org/10.1016/j.exger.2004.06.016

Vite, C., Horvath, A. S., Neff, G., and Møller, N. L. H. (2021). Bringing human-centredness to technologies for buildings: An agenda for linking new types of data to the challenge of sustainability. ACM International Conference Proceeding Series. https://doi.org/10.1145/3464385.3464711

White, G., Zink, A., Codecá, L., and Clarke, S. (2021). A digital twin smart city for citizen feedback. Cities, 110. https://doi.org/10.1016/j.cities.2020.103064

Willcox, D. C., Willcox, B. J., Hsueh, W. C., and Suzuki, M. (2006). Genetic determinants of exceptional human longevity: Insights from the Okinawa centenarian study. Age, 28(4), 313–332. https://doi.org/10.1007/s11357-006-9020-x

Yao, J. F., Yang, Y., Wang, X. C., and Zhang, X. P. (2023). Systematic review of digital twin technology and applications. Visual Computing for Industry, Biomedicine, and Art, 6(1). https://doi.org/10.1186/s42492-023-00137-4

Zhong, W., Schröder, T., and Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. Frontiers of Architectural Research, 11(1), 114–141. https://doi.org/10.1016/j.foar.2021.07.006

Zhong, W., Schroeder, T., and Bekkering, J. (2023). Designing with nature: Advancing three-dimensional green spaces in architecture through frameworks for biophilic design and sustainability. Frontiers of Architectural Research, 12(4), 732–753. https://doi.org/10.1016/j.foar.2023.03.001

4 Smart homes & inclusive communities: **Conference paper**

VR-enabled Digital Twin System Architecture of User-centred Living Labs: A UX Study with Older Adults

Peyman Najafi[1*,2], Gerald Gosselink-Ramos[2], Masi Mohammadi[1,2]

[1] The Chair of Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

*Corresponding author: Peyman Najafi (peyman.najafi@han.nl)

Abstract: This paper introduces the concept of Virtual Reality (VR)-enabled digital twin living labs, which are precise virtual replicas of real-world living labs, and explores their potential in housing research and development. The study outlines the system architecture of a VR-enabled digital twin living lab at the building scale, the Empathetic Home Digital Twin, and investigates the user experience of older adults engaging within this innovative system. The research employs a natural observation method to study the interactions, feedback, and implications for empathetic design. The findings highlight the importance of context familiarity, collective engagement, and intuitive design in building trust and promoting the acceptance of new technologies among older adult users. Key design recommendations, such as optimal VR session duration, gradual adaptation to the VR environment, concise orientation sessions, simplified interaction dynamics, seamless communication mechanisms, and an intuitive user interface, are provided for designing a VR experience tailored to engage older adults. The study acknowledges certain limitations, such as the need for more age-appropriate VR equipment and the small sample size of participants and suggests addressing these limitations in future studies. The potential of VR-enabled digital twins in housing research and development is significant, and future studies can explore their full potential to transform living lab approaches within housing research and development.

Keywords: VR-enabled digital twin, Living labs, User experience, Older adults, Empathetic design

1. Introduction

In recent years, living labs have emerged as a groundbreaking approach within the practice-oriented research ecosystem governing housing research and development. A living lab transcends conventional laboratory settings by integrating real-world contexts and user participation into the co-development and evaluation of innovations, technologies, products, or services (Følstad, 2008; Kareborn & Stahlbrost, 2009; Hossain et al., 2019). Despite the significant added value that living labs offer to current housing research and development, integrating innovative technologies into these real-world settings continues to present substantial challenges. These challenges include the complexity of system integration, leading to extended development cycles, the need for significant financial investments for the acquisition, installation, and maintenance of prototypes, and the considerable physical effort required for co-modifications and adjustments to accommodate new configurations (Fehrer et al., 2024; Leal Filho et al., 2023; Ruijer & Meijer, 2020; Hossain et al., 2019). These challenges highlight the need for a more agile and modular approach in the co-development and deployment of innovations within living lab approaches.

Over the last five years, the evolution of Information and Communication Technology (ICT), Internet of Things (IoTs), cloud computing, and immersive technologies has opened up unprecedented opportunities for adopting more flexible and modular frameworks within living labs. A notable innovation in this arena is the use of Virtual Reality (VR)-enabled digital twins (Jiang et al., 2021; Sepasgozar & Shirowzhan, 2024). A VR-enabled digital twin is a precise virtual replica of a real-world living lab. The use of a VR-enabled digital twin holds several promises, including: 1) the simulation of technological applications in a cost-effective and time-efficient manner, eliminating the need for physical alterations (Tagliabue et al., 2021; Molinari & Rolando, 2020; Lu et al., 2020; Argota Sánchez-Vaquerizo, 2022) ; 2) the rapid iteration and testing of Proof of Concepts (POCs) within a virtual environment, thereby reducing development cycles and physical exertion (Najafi et al., 2023; Bungay et al., 2021; Lu et al., 2020); and 3) the improved scalability and adaptability of POCs, thereby broadening the scope for experimentation and refinement without the financial and logistical constraints associated with conventional living labs (Jia et al., 2022; Zhang et al., 2022;). Today, VR-enabled digital twin living labs are being explored and utilized across various sectors, including energy transition (Opoku et al., 2024), agriculture (Majore & Majors, 2022), education systems (Tagliabue et al., 2021), and inclusive decision supports systems (Najafi et al., 2021).

While embedding such cutting-edge technologies into living labs can represent a pioneering contribution, it is imperative to note that success in living lab approaches is not measured by the sophistication of the technology, but by the harmonious orchestration of enriched experiences and meaningful human engagement that it facilitates. In other words, a system architecture at the intersection of smart-driven technologies, the cyber (physical and virtual) living environments, and meaningful and intuitive stakeholder involvement during the decision-making process is a prerequisite for a VR-enabled digital twin living lab approach. However, outlining such a system architecture is a key question that this paper aims to explore.

This study aims to outline the system architecture of a VR-enabled digital twin living lab at the building scale, namely the Empathetic Home Digital Twin. It then scrutinizes the experience of users (older adults aged 55+) engaging within these innovative systems, employing a natural observation method, and focusing on:

I. Usability, and the perceived ease of use of such a system.
II. Identifying and analysing key design elements and interactions that foster an empathetic user experience, showcasing the potential or challenges.
III. Developing design recommendations to steer future innovations within the living lab research field.

Following this introduction, Section 2 details the system architecture employed in designing the VR-enabled digital twin living lab. Section 3 introduces the natural observation method and unveils the user experience study with older adults, concentrating on their interactions, feedback, and the subsequent implications for empathetic design. The discussion in Section 4 synthesizes insights from the user experience study, placing them within the wider scope of user-centered research. Section 5 encapsulates the study's key contributions and acknowledges its limitations for consideration in future research within the field of user-centered living labs.

2. Methods

2.1 Case study: Empathic Home living lab

“Empathic Home” is a user-centric living lab proposed by Mohammadi (2020) that seeks to merge physical infrastructure, such as homes, with technological advancements to create a living environment that intuitively responds to and anticipates the inhabitants' needs (Mohammadi, 2020). This living lab, with a three-story structure and a ground floor area of approximately 65 square meters, is situated within the IPKW industrial park in Arnhem, The Netherlands (Lieshout, 2023) (Figure 1, left). The Empathic Home venture has yielded effective POCs for implementing empathetic living environments. One such POC is the Guiding Environment, which supports independently living seniors with dementia with General Daily Activities (GDA), such as circadian rhythm, at their home environments (Grave, 2019). Within the Empathic Home living lab, these POCs often incorporate technological components, such as IoT sensor networks, intelligent user interfaces, and adaptable environmental controls to maintain and increase the autonomy of older adults in their living environment.

Living Lab Empathic Home

Digital Twin Empathic Home (VR-enabled)

Figure 1.Empathic Home Living Lab and its digital counterpart.

2.2 System architecture

The system architecture of the VR-enabled Empathic Home employs a mixed-media prototyping approach. This method incorporates HCI devices, particularly VR, real-time data synchronisation between the Empathic Home's real-world structure and its virtual counterpart, and the home user (Figure). The principal components of the systems architecture are as follows:

I. **Physical structure:** The physical component of the Empathic Home includes the building itself, outfitted with IoT sensors and actuators for environmental monitoring and control, such as temperature, humidity, lighting, and motion tracking. The physical components are integrated through a local cloud-based infrastructure, called “Home Assistant.” The Home Assistant is a smart home platform enabling residents of the Empathic Home living lab to automate, control, monitor, and enhance their comfort, security, and convenience.

II. **Virtual Building Information Model (V-BIM)**: The V-BIM of the Empathic Home is 3D modelled using Autodesk Revit, followed by enhancements in Unity, a game engine, for texturing, rendering, and data workflow exchange. This dual approach can leverage the strengths of both platforms to create a dynamic digital twin environment, capable of interacting with the real-world Empathic home through cloud-computing computation.

III. **Broker:** It creates a bidirectional communication flow between the real-world Empathic Home and its digital counterpart. The VR-enabled digital twin of Empathic Home broker encompasses five components:

IV. **Cloud computing:** Provides the backbone for data storage, computational power, and analytics, facilitated through a dual-cloud architecture to meet both functional and computational demands.

V. **Messaging protocol:** Implements Message Queuing Telemetry Transport (MQTT) for efficient and reliable communication among the IoT ecosystem, ensuring robust data exchange and system responsiveness.

VI. **Automation:** Home Assistant serves as customisable platform for enabling the automation of smart devices. This platform receives messages, processed via the MQTT protocol from various IoT devices within the Empathic Home, and translate these messages into specific actions or adjustments to the home environment.

VII. **Application Programming Interface (API):** This API facilitates the creation of dynamic and interactive virtual models that can mirror the physical state of the Empathic Home in real-time. Through MonoBehaviour scripts, the virtual Empathic Home dictates the behaviour of virtual objects, for examples, lights, within the Unity environment, enabling them to respond to user interactions, sensor data, and system commands. This interaction is not unidirectional; commands from the virtual environment can be translated back to physical actions within the home via the Home Assistant platform. The API thus supports a seamless interaction loop between the virtual and real-world Empathic Home, ensuring that changes in the digital twin can affect corresponding adjustments in the real-world environment.

VIII. **VR interface**: Acts as the user interaction frontier to engage with the Empathic Home digital twin.

IX. **Home user:** The stakeholders stand at the core of the system architecture, with their interactions via VR interfaces playing a key role in the digital twin of Empathic Home. The stakeholder can create a personalised and adaptive living environment that adjusts to their behaviours, preferences, and needs (Figure2).

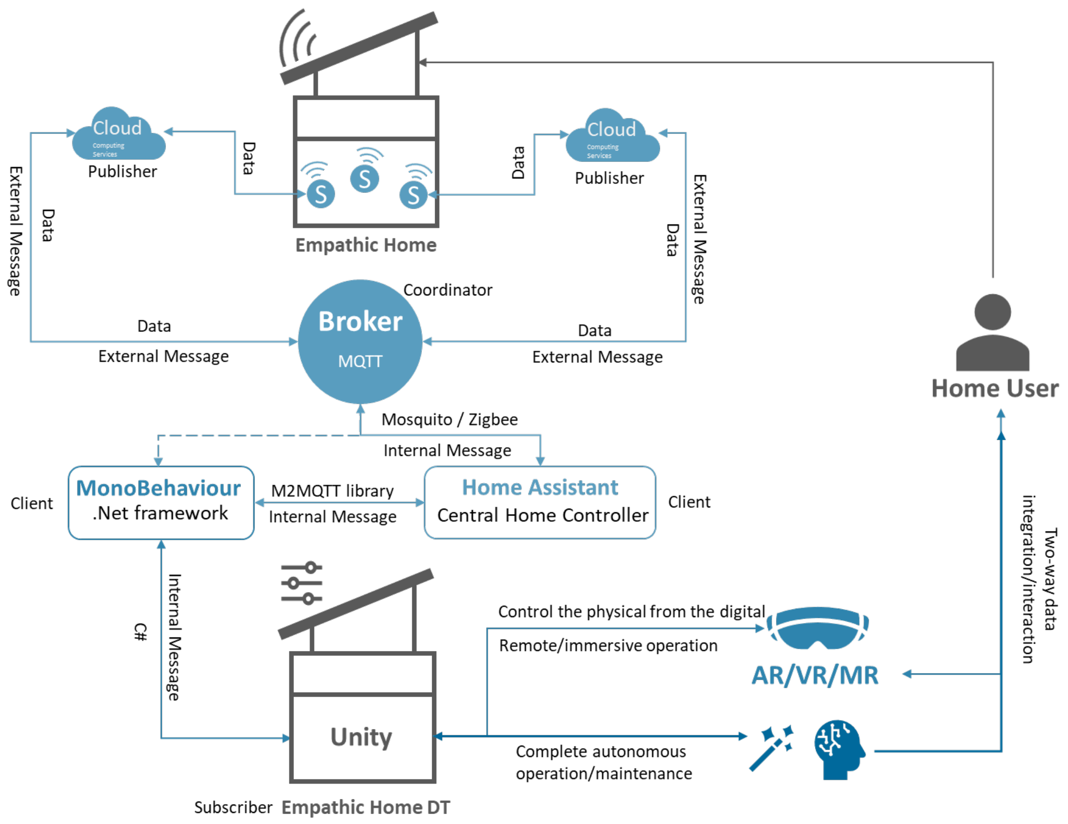


Figure 2. Conceptual system architecture of the VR-enabled digital twin of Empathic Home.

3. Results and analysis

3.1 User experience study

We adopted naturalistic observation methodology to scrutinise the user experience of the participants engaging with the VR-enabled digital twin of the Empathic Home living lab. This method was chosen to ensure the authenticity of interactions by observing participants in their natural environment, devoid of any experimental manipulation or interference (Angrosino, 2016). Our objective was to capture genuine user behaviours and reactions in real-world settings, thereby providing insights into the usability and effectiveness of a VR-enabled digital twin living lab for older participants.

A cohort of five participants (approximately 55 years old), with average postgraduate levels of education but no prior VR experience participated during the user experience study. They engaged with the digital twin model, which was also displayed on a 2D screen for observation by others. This setup facilitated an in-depth analysis of:

I. **User initial perception**: Assessing the session setup for user convenience, engagement with the POCs, usability, ease-of-use for various functions (e.g., haptic feedback, hand gestures), user reactions to immersion, and overall satisfaction.

II. **Design considerations**: Focusing on VR device features, session duration, environmental adaptation, interaction dynamics, data handling, and user interface design, aiming for insights to refine these aspects in future developments.

Our observations revealed significant insights into older adult's interactions and experiences, providing a foundation for enhancing VR-enabled digital twin models for this demographic.

4. Discussion

This study investigated the experiences of older adults interacting with a VR-enabled digital twin prototype, focusing on capturing their authentic behaviour and reactions within a natural setting to glean first-hand insights. The research findings have the potential to impact multiple disciplines, including ICTs, smart architectural technologies, and living labs by providing valuable insights on the development of methods and ICT technologies attuned to the needs of end users. Specifically, these insights are vital for developing interfaces and systems that accommodate the unique requirements and preferences of older adults, ensuring their inclusion in the evolving user-centric digital twins for living lab landscape. These insights are detailed below:

Insights from the experiment

A central finding of our investigation supports and expands upon the observations made by Merriman et al. (2016), who identified that engagement among older adult users is markedly improved in environments that are familiar to them (Merriman et al., 2016). The inference drawn is that integrating VR technologies into the BIM of the familiar settings like homes for older adults, and tailoring these technologies to their interests, can make VR seem less daunting and more accessible to them.

Further, our research advocates for a broader interpretation of 'familiar settings' to encompass not merely the VR environments themselves but also the social and cultural contexts that underpin both the experimental setup and the user experiences. This expansion appears important for building trust and promoting the acceptance of new technologies among older adult users. Specifically, our study highlights the following insights:

I. **Familiarity with the experiment's environment:** Placing VR experiments in environments recognised by participants, such as communal areas within their living spaces, can enhances their trust in the experimental process, particularly for those encountering VR-enabled products for the first time. We underscore that the selection of familiar settings for conducting the experiment has a beneficial impact on enhancing older adult participants' confidence to facilitate their engagement in a more receptive manner.

II. **Collective engagement:** Incorporating group dynamics into VR interventions has been demonstrated to boost participant engagement and confidence (Gomez et al., 2019). Our observations also indicate that enabling older adults to participate in groups, whether through forming cohorts with friends or neighbours, can foster a supportive environment that lessens reluctance towards technological interaction. This model of collective participation also seems promising for overcoming psychological barriers to VR technology adoption and increasing the experiment's effectiveness.

III. **Communication strategy:** our findings is advocating HCI research for adaptable interaction modalities to accommodate user preferences and limitations. We observed that communicating in the participants' local language significantly ensures clear understanding and maintains engagement. The preference for verbal over written communication among senior participants necessitates provisions for oral interviews and the incorporation of auditory feedback mechanisms within the VR experience.

VR-enabled digital twin experience: design consideration for the senior users:

Our study also elucidates several factors that can be considered when designing VR experiences tailored to the needs of users:

I. **Intuitive design and usability:** Our findings underscore the critical role of intuitive design – enabling the users to understand how to use the prototype without much effort. This principle is in concordance with the Technology Acceptance Model (TAM), which posits that the perceived ease of use is a significant criteria in the adoption of technology (Marangunić & Granić, 2015). We also recommend prioritising other criteria such as comfort, and safety when selecting VR headsets and related accessories. Specifically, it is advisable to choose headsets that are lightweight and adjustable, catering to diverse head sizes and visual requirements. Additionally, incorporating VR controls that demand minimal manual dexterity and ensuring auditory cues are clear and adaptable to various hearing abilities are essential consideration.

II. **Session duration:** The cognitive and physical stamina of senior users should inform the optimal duration of VR sessions. Our findings suggest a maximum engagement threshold that avoids fatigue or discomfort, ideally not exceeding 20 minutes. This duration ensures that participants remain engaged and comfortable, without overwhelming them, thereby maximizing the benefits of the VR experience.

III. **Adaptation:** Initial exposure to VR should emphasize comfort and gradual acclimatization to the virtual environment. While walking modes can offer benefits for immersion and wayfinding, seated navigation modes are recommended to ensure a comfortable and focused experience. This consideration is crucial in minimizing the risk of disorientation or discomfort among senior participants.

IV. **Introduction to VR environment:** The entry process into the VR environment should be carefully managed, starting with an immersive setting that is familiar, pleasant, or calming. This should be followed by a concise orientation session to prepare participants for the experience. Such an approach facilitates a smooth transition into the virtual world, building participants' readiness and confidence.

V. **Interaction dynamics**: The design should minimize the need for complex interactions that require significant input from the user, such as pressing buttons or using haptic feedback. In situations where user input is necessary, manual controls should be readily accessible to the experimenter to assist in navigating any difficulties. Simplifying interaction dynamics ensures that users can engage with the content without becoming overwhelmed by the technology.

VI. **Communication/Instruction:** Communication from the experimenter to the participant during the VR session should be integrated within the VR environment whenever possible. Overlaying the experimenter's voice within the virtual setting, rather than having it come from the external world, helps maintain immersion and prevents confusion. This method supports a seamless experience, reinforcing the sense of presence within the virtual environment.

VII. **Interface design:** The design of user interfaces and interaction mechanisms within VR must adhere to principles of simplicity, clarity, and accessibility. Features should include large, legible text, intuitive navigation paths, and high-contrast visual elements to accommodate visual impairments common among older adults. Such design principles ensure that the VR experience is not only accessible but also engaging for senior users.

5. Conclusion

In conclusion, the system architecture of the VR-enabled digital twin living presented in this paper can be considered a forward-thinking approach within the practice-oriented research ecosystem governing housing research and development. Furthermore, the user experience, particularly among older adults, investigated in this paper, can provide valuable insights into designing, implementing, and assessing the potential impact of such user-centric approaches within future inclusive decision-making systems.

Also, the findings of this study, including the context familiarity, collective engagement, and intuitive design, can be considered as driving factors for building trust and promoting the acceptance of new technologies among older adult users in future studies. Furthermore, key design recommendations, including an optimal VR session duration, gradual adaptation to the VR environment, concise orientation sessions to prepare participants for the experience, simplified interaction dynamics, seamless communication mechanisms, and an intuitive user interface, are driving factors when designing a VR experience tailored to engage older adults.

Although VR-enabled digital twins offer significant potential for living lab approaches, this study acknowledges certain limitations. The current VR equipment used in the study may need to be more age-appropriate, leading to issues such as dizziness, fatigue, or disorientation during the experiment, particularly among participants with health issues. Additionally, the sample size of participants is small, which may affect the generalization of the findings. Personal biases during the experiment due to natural observation behaviours may also affect the results.

To maximize the potential of VR-enabled digital twins in housing research and development, future studies should address these limitations and explore the potentials further. Building upon this research, future studies can harness the full potential of VR-enabled digital twins to transform living lab approaches within housing research and development.

References

Grave, A. (2019). Progress project: The Guiding Environment: The design of a guiding Angrosino, M. V. (2016). Naturalistic observation. Routledge. https://books.google.com/books?hl=en&lr=&id=nKcYDQAAQBAJ&oi=fnd&pg=PT8&dq=naturalistic+observation+methodology+&ots=WSZvengsx0&sig=0sSjTGm3wvhtjiLqQwJbW_sBBTI

Argota Sánchez-Vaquerizo, J. (2022). Getting real: The challenge of building and validating a large-scale digital twin of Barcelona's traffic with empirical data. ISPRS International Journal of Geo-Information, 11(1), 24.

Bennett, J. W. (2017). The ecological transition: Cultural anthropology and human adaptation. Routledge.

Bungay, H., Wilson, C., Dadswell, A., & Munn-Giddings, C. (2021). The role of collaborative working between the arts and care sectors in successfully delivering participatory arts activities for older people in residential care settings. Scopus. https://doi.org/10.1111/hsc.13290

Dell'Era, C., & Landoni, P. (2014). Living Lab: A Methodology between User-Centred Design and Participatory Design. Creativity and Innovation Management, 23(2), 137–154. https://doi.org/10.1111/caim.12061

Fehrer, J. A., Kemper, J. A., & Baker, J. J. (2024). Shaping Circular Service Ecosystems. Journal of Service Research, 27(1), 49–68. https://doi.org/10.1177/10946705231188670

Følstad, A. (2008). Living labs for innovation and development of information and communication technology: A literature review. https://sintef.brage.unit.no/sintef-xmlui/handle/11250/2440026

Grave, A. (2019). Progress project: The Guiding Environment: The design of a guiding environment to stimulate older adults with early-stage dementia to enable them to live longer in their own homes. https://www.hbokennisbank.nl/details/sharekit_han:oai:surfsharekit.nl:c656e15a-13c2-4beb-93bc-afa9bb02980f?q=anne&c=0&p=36

Hossain, M., Leminen, S., & Westerlund, M. (2019). A systematic review of living lab literature. Journal of Cleaner Production, 213, 976–988.

Jia, W., Wang, W., & Zhang, Z. (2022). From simple digital twin to complex digital twin Part I: A novel modeling method for multi-scale and multi-scenario digital twin. Advanced Engineering Informatics, 53, 101706.

Jiang, Y., Yin, S., Li, K., Luo, H., & Kaynak, O. (2021). Industrial applications of digital twins. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 379(2207), 20200360. https://doi.org/10.1098/rsta.2020.0360

Kareborn, B. B., & Stahlbrost, A. (2009). Living Lab: An open and citizen-centric approach for innovation. International Journal of Innovation and Regional Development, 1(4), 356. https://doi.org/10.1504/IJIRD.2009.022727

Leal Filho, W., Ozuyar, P. G., Dinis, M. A. P., Azul, A. M., Alvarez, M. G., Da Silva Neiva, S., Salvia, A. L., Borsari, B., Danila, A., & Vasconcelos, C. R. (2023). Living labs in the context of the UN sustainable development goals: State of the art. Sustainability Science, 18(3), 1163–1179. https://doi.org/10.1007/s11625-022-01240-w

Lieshout, T. van. (2023, January 23). Empathische Woning—DEEL. https://deelacademy.nl/empathische-woning/

Lu, Q., Parlikad, A. K., Woodall, P., Don Ranasinghe, G., Xie, X., Liang, Z., Konstantinou, E., Heaton, J., & Schooling, J. (2020). Developing a Digital Twin at Building and City Levels: Case Study of West Cambridge Campus. Journal of Management in Engineering, 36(3), 05020004. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000763

Majore, G., & Majors, I. (2022). Digital twin modelling for eco-cyber-physical systems: In the case of A smart agriculture living lab. Proceedings of PoEM Forum, 22, 98–112. https://ceur-ws.org/Vol-3327/paper09.pdf

Marangunić, N., & Granić, A. (2015). Technology acceptance model: A literature review from 1986 to 2013. Universal Access in the Information Society, 14, 81–95.

McDonagh, D., & Thomas, J. (2010). Disability + Relevant Design: Empathic Design Strategies Supporting More Effective New Product Design Outcomes. The Design Journal, 13(2), 180–198. https://doi.org/10.2752/175470710X12735884220899

Merriman, N. A., Ondřej, J., Roudaia, E., O'Sullivan, C., & Newell, F. N. (2016). Familiar environments enhance object and spatial memory in both younger and older adults. Experimental Brain Research, 234(6), 1555–1574. https://doi.org/10.1007/s00221-016-4557-0

Mohammadi, M. (2020). Empathic AI for Assisted Living: Experience Lab-Demo. https://research.tue.nl/en/publications/empathic-ai-for-assisted-living-experience-lab-demo

Mohammadi, M. (2022). Shaping an empathic living environment: Design research as an incentive and medicine for healthy living. In Applied Design Research (pp. 207–216). CRC Press. https://www.taylorfrancis.com/chapters/oa-edit/10.1201/9781003265924-19/shaping-empathic-living-environment-masi-mohammadi

Molinari, M., & Rolando, D. (2020). Digital twin of the Live-In Lab Testbed KTH: Development and calibration. International Conference Organised by IBPSA-Nordic, 13thâ€"14th October 2020, OsloMet. BuildSIM-Nordic 2020. Selected Papers. https://sintef.brage.unit.no/sintef-xmlui/handle/11250/2683271

Najafi, P., Mohammadi, M., van Wesemael, P., & Le Blanc, P. M. (2023). A user-centred virtual city information model for inclusive community design: State-of-art. Cities, 134, 104203. https://doi.org/10.1016/j.cities.2023.104203

Najafi, P., Mohammadi, M., Le Blanc, P. M., & Van Wesemael, P. (2021). Experimenting a Healthy Ageing Community in Immersive Virtual Reality Environment: The Case of World's Longest-lived Populations. 2021 17th International Conference on Intelligent Environments (IE), 1–5. https://doi.org/10.1109/IE51775.2021.9486595

Opoku, D.-G. J., Perera, S., Osei-Kyei, R., Rashidi, M., Bamdad, K., & Famakinwa, T. (2024). Digital twin for indoor condition monitoring in living labs: University library case study. Automation in Construction, 157, 105188.

Ruijer, E., & Meijer, A. (2020). Open Government Data as an Innovation Process: Lessons from a Living Lab Experiment. Public Performance & Management Review, 43(3), 613–635. https://doi.org/10.1080/15309576.2019.1568884

Sepasgozar, S., & Shirowzhan, S. (Eds.). (2024). Digital Twin Adoption and BIM-GIS Implementation (1st edition). Routledge.

Tagliabue, L. C., Cecconi, F. R., Maltese, S., Rinaldi, S., Ciribini, A. L. C., & Flammini, A. (2021). Leveraging digital twin for sustainability assessment of an educational building. Sustainability, 13(2), 480.

Warnke, P., Weber, M., & Leitner, K.-H. (2008). TRANSITION PATHWAYS TOWARDS USER-CENTRIC INNOVATION. International Journal of Innovation Management, 12(03), 489–510. https://doi.org/10.1142/S136391960800200X

Zhang, H., Qi, Q., & Tao, F. (2022). A multi-scale modeling method for digital twin shop-floor. Journal of Manufacturing Systems, 62, 417–428.

4 Smart homes & inclusive communities: **Abstract livinglab DEEL**

Brains4Buildings

Olivia Guerra-Santin[1], Nitant Upasani[1], Masi Mohammadi[1]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Olivia Guerra-Santin (o.guerra.santin@tue.nl)

Brains4Building's Energy Systems (B4B) is a comprehensive project targeting the optimization of energy consumption within utility buildings. By leveraging extensive data from smart meters, building management systems, and Internet of Things (IoT) devices, the project aims to reduce energy usage, enhance comfort levels, adapt flexibly to user behavior and local energy dynamics, and mitigate installation maintenance expenses. This pursuit is supported by the improvement of Machine Learning and Artificial Intelligence models and algorithms, enabling faster and more efficient energy management solutions tailored to commercial and institutional buildings.

Initiated within the framework of TKI Bouw & Techniek, the Brains4Buildings initiative aligns with the broader objectives of fostering open innovation and knowledge sharing across multi-year programs. The 39 partners include knowledge institutions, technology developers, industry associations, and more.

Despite advancements, modern buildings still suffer significant energy losses and operational inefficiencies. The integration of smart technologies seeks to rectify this, transforming buildings into intelligent entities capable of informed decision-making. However, current models and algorithms face limitations in speed and efficiency, hindering widespread implementation.

The B4B project aims to imbue buildings with operational intelligence, leading in a paradigm shift towards energy-efficient and adaptable structures. Key objectives include the development of validated software plug-ins for enhanced monitoring and control, leading to substantial energy savings and reduced maintenance costs. Additionally, the project endeavors to refine user-centric interfaces, establish standardized indicators for building readiness, and devise methodologies for seamless data integration across smart infrastructures.

Within the B4B project, several living labs are used to develop, test and validate the technologies and algorithms. The living labs within the project are owned by the Hague University of Applied Sciences, Building 28 and the Green Village at TU Delft, the Atlas building at TU Eindhoven, among others. Results are further validated in living labs owned by the industry partners.

Partners:

TUDelft, Eindhoven University of Technology, TNO, Avans University of Applied Sciences, The Hague University of Applied Sciences, HAN University of Applies Sciences, Windesheim University of Applies Sciences, AirTeq, AptaTechnologies, ArtEnergy, BAM, G100 Building Chess, Qien, Deerns, Almende, the Dutch Green Building Council, DWA, Dyseco, Binnenklimaat Nederland, Heroes, Kuijpers, Kropman, NEN, ONexus, OfficeVitae, FHI, Peutz, Phillips, Renor, Royal Haskoning, Sensing360, Heijmans, Spectral, Spie, SystemAir, Unica, WOI, Bouw&Techniek, W/e.

Start date LivingLab: May 2021

End date LivingLab: May 2025

4 Smart homes & inclusive communities: **Abstract livinglab DEEL**

Space for Adoption

Exploring smart care dynamics and interventions in Dutch nursing homes

Masi Mohammadi[1,2], Coosje Hammink[1], Ruth Bles[1], Laurèn Pennings[2]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Masi Mohammadi (masi.mohammadi@han.nl)

An increasing number of nursing homes are integrating smart spaces as tools for activities such as day care, therapy, and to enhance the ambiance and activities of communal areas. These technologies demonstrate potential to boost social interaction, increase agency, and mitigate misunderstood behaviours among people with dementia. Initial feedback from care professionals and informal carers is positive; however, there is a noted decline in usage over time.

This research aims to investigate the capabilities and actual usage of these smart care solutions through targeted operational mechanisms and strategic interventions across five Dutch care organizations. These organizations will serve as living labs over the next four years for the 'Space for Adoption' study, which focuses on the deployment of smart spaces among care professionals to reduce long-term pressure on formal and informal care providers.

Utilizing a mixed-methods approach, this study employs the extended Unified Theory of Acceptance and Use of Technology (UTAUT) model, augmented with insights from care professionals and observations within care home settings. It identifies key barriers to technology utilization and suggests modifications to the UTAUT model to better address the complexities of dementia care.

The study underscores the critical need to consider both technological and socio-psychological factors to successfully integrate technology within the organizational and spatial contexts of nursing homes. Outcomes include the development of tailored strategies that enhance lasting technology adoption and the refinement of theoretical models to facilitate effective integration. These contributions aim to impact both practice and policy, potentially easing caregiver burdens and improving patient outcomes through more efficient technology use. This study highlights the necessity for a comprehensive and integrative approach to technology adoption

in dementia care, ensuring that solutions are not only technically effective but also culturally and organizationally harmonized within care environments.

Partners: Care organizations: Archipel, tanteLouise, Oktober, Vilente, and Ijsselheem and Knowledge institutions: Windesheim, Zuyd University of Applied Sciences, Vilans, Eindhoven University of Technology, HAN University of Applied Sciences and DEEL

Funded by: Dutch Research Council under the Taskforce for Applied Research SIA RAAK-PRO program.

Start date LivingLab: 2024
End date LivingLab: 2028

4 Smart homes & inclusive communities: **Abstract livinglab DEEL**

The social added value of clustered housing in an ageing society

Nienke Moor[1], Kim Hamers[1], Masi Mohammadi[2]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Nienke Moor (Nienke.moor@han.nl)

With the growing influx of older adults, cohesion in low-income neighborhoods is deteriorating: more people need support and care, but fewer residents are able to support their fellow residents. Housing corporation Woonzorg Nederland therefore focuses on clustered housing in which (organized) encounters between residents are facilitated by at least one communal space for socializing. In collaboration with Woonzorg Nederland, researchers from DEEL therefore examined 1) the social added value of clustered housing for older tenants, and 2) how clustered living should be spatially designed to optimally promote encounters between residents. To answer these questions, a mixed methods approach has been applied. In three case studies, the opportunities, barriers, and risks related to clustered housing were examined using qualitative methods, such as in-depth interviews with older tenants and building managers. In addition, quantitative research was conducted using real estate data and survey data collected among building managers and older tenants (55+) of Woonzorg Nederland. Based on this data, four types of clustered housing were distinguished, which vary according to spatial and social-organizational features. The findings of the study show that tenants of clustered housing types are not less lonely, but do have more contact with fellow residents than tenants of non-clustered housing types, which in some cases even resulted in more neighborly support. In clustered housing, residents not only meet more often in an organized context, but often there are also more opportunities for spontaneous encounters. While organized encounters are associated with repeated and friendly contact, spontaneous encounters are associated with public familiarity and feelings of trust and security. However, only residents who are willing and able to participate, seem to socially benefit from clustered housing.

Partners: Woonzorg Nederland

Start date LivingLab: June 2020

End date LivingLab: May 2024

4 Smart homes & inclusive communities: **Abstract livinglab DEEL**

Smart, empathic communities
A methodology to connect and activate neighbourhoods

Masi Mohammadi[1,2], Anne Grave[1*], Sophie Peters[2], Leonie van Buuren[1], Peyman Najafi[2], Chuan Ma[1]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

*Corresponding author: Masi Mohammadi (masi.mohammadi@han.nl)

Socio-economic and health disparities significantly fragment societies, a reality starkly evident in social housing neighbourhoods. As demographic shifts escalate, marked by increased health vulnerabilities, the lack of (social) care support and a rising number of dementia cases, profoundly impacts social and overall life quality in these settings. Innovative spatial strategies are required to address these inequalities and promote fair community development. Proven social and technological interventions have demonstrated their potential to enhance social cohesion when seamlessly integrated into the fabric of neighbourhoods.

In the city of Waalre, Netherlands, key stakeholders—including a housing association, care organization, local municipality, and a university—have united to develop a SLIM (Socially healthy, Livable, Innovative, and huMan-oriented) neighbourhood in collaboration with its inhabitants.

This quadruple helix collaboration focuses on fostering self-management and (socially) healthy behaviours, improving community participation among residents of three social rental complexes and a nursing home. Advanced techno-spatial interventions, such as augmented reality environments, and social strategies like community-led development workshops, engage and activate older residents, enhancing their satisfaction, mental health, and autonomy.

The project leverages citizen science and co-creation, utilizing research fairs, group interviews, and digital twinning to investigate social interaction and mental health dynamics.

Key elements like (mental) accessibility, inclusiveness, and belonging are pivotal, necessitating a shift by (local) governments and professionals from problem and task-oriented thinking to more integrated and holistic thinking methods. An integrated effort in this living lab has led to a multi-level governance plan improving policy development for engaging older citizens in urban planning. These methods align community-led decision-making with democratic processes, ensuring the accessibility of smart living solutions.

Over the next four years, the focus will be on transforming these insights into actionable spatial models, deepening technological integration, and empirically validating these models. The

incorporation of socio-technological innovations will be crucial, advancing spatial planning through data-driven insights and real-time feedback.

Partners: Housing association Wooninc., Care organization Oktober, Eindhoven University of Technology, Municipality of Waalre and DEEL

Funded by: Wooninc. Oktober, Dutch Research Council (NWO) and Care Research Netherlands (ZonMw)

Start date LivingLab: 2020
End date LivingLab: 2028

4 Smart homes & inclusive communities: **Abstract livinglab DEEL**

Spaces to Meet
Strategies for maximizing interaction and usage of meeting spaces in social housing

Masi Mohammadi[1,2], Nienke Moor[2], Ruth Bles[2], Liesbet Rabbinge[2], Erik Groen[2]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

*Corresponding author: Masi Mohammadi (masi.mohammadi@han.nl)

Meeting spaces within social housing complexes are proposed as interventions aimed at reducing social isolation and enhancing community cohesion. These spaces are designed to facilitate essential social interactions, fostering community bonds, and improving the well-being of residents. They also serve as potential venues for the early detection of social, health, and economic issues, enabling proactive interventions. However, considerable variation exists in the effectiveness and usage of these spaces, raising questions about the factors that influence their use and how techno-spatial, organizational, and social resources can be optimally deployed to enhance interactions, particularly among older inhabitants.

This research is grounded in social interaction theory and the socio-ecological model, focusing on the spatial, social, and organizational factors that influence the dynamics of meeting spaces. Literature reviews, observations, and contextual analyses were conducted across sixteen meeting spaces in Nijmegen and its surrounding areas. Interviews with professionals and residents—both users and non-users—provided insights into motivations and barriers to use.

Co-creative sessions facilitated the development of spatial modifications and smart furniture designs, such as an interactive table aimed at encouraging spontaneous conversations. Although these interventions were implemented in a living lab setting and have not yet undergone evaluation.

Based on spatial characteristics and usage patterns, the study identifies four distinct types of meeting spaces within social housing: Activity nexus, Communal living room, Chatterbox café, and Neighbourhood nest, each designed to foster unique interactions and meet specific community needs. While each type is seen as potentially valuable, the study underscores the necessity for further research to fully realize their potential as community-building tools and address challenges of inclusivity and equitable access. The research recognizes the potential of meeting spaces to boost community interaction but observes that usage is often limited to regular groups, potentially not reaching the most socially isolated. Issues like threshold fear,

ownership, and claiming behaviour limit their broader appeal, compromising the ideal of inclusivity. The conclusion asserts these spaces can enhance social interaction and well-being but stresses the need for a nuanced approach to address barriers and ensure equitable benefits. The study emphasizes incorporating gender and cultural diversity to make spaces universally inclusive and expand interaction opportunities.

Partners: Housing association Talis, HAN University of Applied sciences, and DEEL
Funded by: Talis and the Taskforce for Applied Research SIA, program KIEM.

Start date LivingLab: 2020
End date LivingLab: 2024

4 Smart homes & inclusive communities: **Abstract livinglab DEEL**

Strengthening community resilience for the empowerment of older adults in Dutch social housing.

Nienke Moor[1], Moniek van Loon[1], Masi Mohammadi[1,3], Kim Hamers[1], Sophie Peters[1], Wouter Rijke[1], Marijn van de Weijer[2], Laurèn Pennings[3]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] Zuyd University of Applied Sciences, The Netherlands

[2] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Nienke Moor (Nienke.moor@han.nl)

Housing corporations are dealing with a growing group of older adults who require suitable housing that aligns with both their physical and social needs. Together with their collaborative partners, housing corporations contemplate ways to empower seniors as much as possible in their residential environment. This is in line with Dutch policy, which not only focuses on increasing self-reliance among seniors living at home but also emphasizes the crucial role of fostering communal support. In this research project, which involves collaboration between academic institutions, housing corporations, and a healthcare facility, we explore how to best shape community resilience in the residential environment, in such a way that seniors who need it can also benefit from it. Our central question reads: How can we assist professionals of housing corporations and their collaborative partners in designing a resilient residential environment, both socially and spatially, that supports communal support to empower diverse profiles of seniors in social housing?

To address this question, we conduct research in five Living Labs, which consist of residential complexes from the participating housing corporations, each varying in relevant social-organizational and spatial characteristics. Within these Living Labs, we aim to gain deeper insights into a. the profiles of seniors who may (or may not) benefit from neighborly support, and b. the environmental features that either promote or hinder community resilience. We collect the required data via a mixed method approach, in which we combine (group) interviews with residents and professionals with a spatial analysis and finally a secondary analysis of survey data among residents. In co-creation with building managers and other (healthcare) professionals, this will culminate in the development of a practical tool, offering concrete guidance, and aiding in the spatial and social-organizational support and shaping of the residential community.

Partners: Woonzorg Nederland, Talis, De Alliantie, De Woonmensen, Woonzorg Flevoland, HAN University of Applied Sciences, Zuyd University of Applied Sciences, Eindhoven University of Technology

Start date LivingLab: 01 September 2023

End date LivingLab: 31 August 2025

4 Smart homes & inclusive communities: **Abstract keynote**

Experiences from livinglabs & lifetime neighbourhoods that care

Ian Spero

Agile Ageing, England

Imagine a future where age is not a barrier, but a gateway to new horizons. A future where technology enables people to maintain their health, their independence and their dignity, well into later life. This is the vision of ISO 25553, a new global standard framework, relating to the design, creation, operation and maintenance of mixed tenure 'Smart Multigenerational Neighbourhoods', where young and old, disabled and able, can co-exist in technologically enabled housing.

By pooling research, expertise and insights, participating stakeholders have the opportunity to revolutionise the design of our neighbourhoods of the future at both the micro and macro levels.

We aim to achieve this by means of a new Centre of Excellence (CoE) located at Imperial and University Colleges London. Through combining applied research, social sciences and humanities perspectives, the Centre aims to provide a comprehensive understanding of the complex interactions between technology and the built environment.

The CoE will drive innovation, foster collaboration between academia and industry, and facilitate the development of sustainable and human-centric solutions for the built environment. Serving as a hub for knowledge exchange,

interdisciplinary research, and practical applications, ultimately contributing to the advancement of urban development and societal wellbeing.

By leveraging the collective expertise of Imperial and UCL, alongside world-renowned academic, private, and public sector partners, we aim to normalise the development of 'Lifetime Neighbourhoods that Care', where putting people and the planet's needs as a priority can combat loneliness, improve quality of life, health/care and wellbeing, while easing the associated burden on health and social care systems.

Join this session to learn more about ISO 25553; the new Centre of Excellence and find out how your organisation can get involved.

4 Smart homes & inclusive communities: **Abstract keynote**

Health and Wellbeing living labs

Evdokimos Konstantinidis

European Network of Living Labs (ENoLL), Greece

According to the European Network of Living Labs (ENoLL), Living Labs are open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities, placing citizens at the centre of innovation. “Open” because it is about tapping into the knowledge and know-how that exist outside one’s organization by engaging with others. “User” centered because Living Labs actively and directly involve, throughout the innovation development process, end-users. Fostering “Innovation”, Living Labs operate as intermediaries among citizens, research organizations, companies and government agencies for joint-value co-creation, rapid prototyping or to scale up innovation and businesses.

The added value of Living Labs is the real-life observation and experimentation. And this calls for cross-disciplinary, cross-sectoral and cross-border experimentation, starting from the regional ecosystems. The challenge in Living Labs is that they can provide value only when the stakeholders from the quadruple helix are actively involved. A living lab in a hospital cannot provide any value to the researchers unless patients, doctors and family members are involved as co-creators.

Over the last few years, Living Labs have emerged as resilient research and innovation infrastructures and have proved to be key to the integration of research and innovation processes in real life settings. To this end, ENoLL in VITALISE H2020 has collected and studied all the services, procedures and tools/devices that Health and Wellbeing Living Labs can provide and has designed the methodology for harmonizing them. The benefit to the wider research community is that they can access any Living Lab Research Infrastructures in a harmonized way. This is aligned with the message coming from the European innovation ecosystem (New European Innovation Agenda, July 2022), where Living Labs are mentioned in one of the 5 flagships as accessible experimentation spaces facilitating innovation.

4 Smart homes & inclusive communities: **Abstract keynote**

Shaping a meaningful, just and viable future of physical work – spaces for transdisciplinary research and innovation

David Abbink[1,2]

[1]Delft University of Technology, Faculty of Mechanical Engineering & Faculty of Industrial Design Engineering, The Netherlands

[2]Scientific Director of FRAIM, The Netherlands

Mounting labour shortages pose a major challenge for many sectors that include physical work. Innovations in technical assistance could contribute to solving this complex challenge, but that is easier said than done. Even if innovations are successful and embraced by the workfloor their impact on the work is not clear in advance. For example, some robots generate efficient profits, but also make work more boring or meaningless, causing staff to disappear. How should we as a society shape the future of work so that it is meaningful, just and viable?

It is very important to integrate different perspectives: innovation experience, academic knowledge (technical sciences and social sciences) and the expertise of professionals on the work floor and from the organizations. This is what the FRAIM research and innovation center aims to achieve: shaping the future of work, with and for professionals. I will share our experiences in projects involving repair & maintenance, baggage handling and nursing, and try to reduce the impact on the manufacturing industry. Specifically, I will talk about the lab spaces that need to be created in order to bridge disciplines and practices, by facilitating conversations, productive conflicts, the co-creation of robotic capabilities and other design processes.

4 Smart homes & inclusive communities: **Abstract keynote**

Standardization strategy in the space construction of institutional senior care facilities - a case study from China

Christina Fang Dai

Antai College of Economics and Management, Shanghai Jiao Tong University, China

*Corresponding author: Christina Fang Dai (fdai@sjtu.edu.cn)

China population is aging at an unprecedented rate, with 297 million people aged 60 or above by the end of 2023, accounting for 21.1% of the country's population. By 2035, this percentage is estimated to exceed 30%, making China one of the most aged countries globally. The Chinese government, from the central to municipal level, have been striving to adopt appropriate policies and allocate adequate resources to meet the growing elder care needs. One such policy stipulates that the number of beds in senior care facilities should reach a certain percentage of the senior population. Consequently, various cities have established their models, such as 9073 (Shanghai), 9064 (Beijing) or 9055 (Wu Han), with the last digit representing the estimated percentage of seniors residing in care facilities.

Encouraged by government initiatives and attracted by the immense market potential, numerous companies diversified into the senior care industry in the last decade, initiating a wave of constructing senior care facilities. While adhering to government regulations and guidelines, many companies have struggled due to their lack of experience and knowledge in senior care facility operations. Designing spaces and environments that cater to senior residents' needs while facilitating efficient service operations has posed a challenge. Moreover, companies must balance property investments with future returns. One strategy adopted by companies is standardizing their design systems and processes to ensure quality, enforce cost control, and enable iterative improvements.

This presentation delves into the standardization strategy adopted by the case company, Joru Elderly Care Industry Group, a comprehensive senior care service provider in China. It will focus on the motivation, implementation, and impact of the strategy, offering insights into the challenges and opportunities within China's emerging senior care industry.

4 Smart homes & inclusive communities: **Abstract workshop**

Future homecare for and with older adults

Camilla Evensson[1], Sarah Latus[2], Coosje Hammink[3]

[1] RISE Research Institutes of Sweden, Sweden

[2] Institute of Medical Technology and Intelligent Systems, TUHH, Hamburg University of Technology, Germany

[3] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

As the ageing population places growing demands on healthcare systems in the North Sea region, the ACE project has emerged to alleviate the burden.

The ACE project is pioneering a future where older adults can live safer, independent lives, by accelerating the use of innovative technologies and solutions for better future homecare.

ACE's transnational and multidisciplinary consortium of 14 partner organizations from six European countries – Sweden, Denmark, Belgium, the Netherlands, France & Germany - is working to prepare formal and informal healthcare providers for the homecare solutions and technology of the future. The project will connect technology and solution providers with networks essential to making an impact and, ultimately, ensure that the end users of these solutions remain independent and healthy in their own homes.

Last autumn the ACE project conducted nine workshops in five countries to identify common challenges and the most pressing needs among all relevant stakeholders connected to homecare. Participants included older adults and their relatives, care givers, care managers, politicians, companies, civil society, and academia. In total approximately 200 individuals participated and contributed to the workshop results.

In our workshop, we will present a summary of the most pressing needs that we have identified, and we will invite the participants in our session to contribute interactively. We would like to tap into your expertise and experience in technology for the future, technology that would be suitable to match with the most pressing needs, to be able to create an attractive future homecare for older adults.

4 Smart homes & inclusive communities: **Abstract workshop**

Social Innovation as motor for smart inclusive environments

Willeke van Staalduinen[1], Silvia Urra Uriarte[2]

[1] AFEdemy, age-friendly environments academy, The Netherlands

[2] Tecnalia, Spain

Smart healthy inclusive living environments foster social participation, independent living and health and well-being of citizens.

- Housing is accessible and equipped to support its inhabitants. It is smart and responsive to meet the needs and challenges in case of impairments or chronic disease.
- Outdoor spaces provide elementary facilities for accessible leisure, care and meetings.

Who would not feel attracted to such living environments for all?

Innovation actors, such as municipal workers, housing developers and care providers in most European countries are initiating or contributing to the realization of such environments. The goal is quite clear, however, the path to it is often challenging and needs much patience and clever maneuvering. The SIRENE project (Social Innovation Responsive Environments Network) brings together multidisciplinary experts to co-create an applicable Framework for innovation actors. The Framework provides insight information on the involvement of multiple stakeholders in ecosystems, funding opportunities, good practices and smart solutions.

In this interactive workshop, we will introduce the Framework and invite the audience to engage in discussions and suggest amendments. Various examples of smart age-friendly initiatives at different scales, such as urban and building contexts, will be showcased. The session will delve into the analysis of how social innovation plays a pivotal role in the development and implementation of these initiatives.

The agenda of the workshop is the following:

- Opening by Willeke van Staalduinen, CEO of AFEdemy, to introduce SHAFE, Smart Healthy Age-Friendly Environments, SIRENE and the Framework
- Contribution by Silvia Urra Uriarte, PhD candidate and Researcher of Tecnalia, about urban planning and age-friendly cities and how social innovation is key.
- Contribution by Anne Grave, MSc, EngD about Designing Neighbourhood Open Spaces to Promote the mental health of the ageing population
- Discussion, questions and amendments

4 Smart homes & inclusive communities: **Abstract workshop**

An empathic approach for connecting health to mobility behaviour in public space

Melissa Bruntlett, Esmee van Selst, Bige Tunçer

RoyalHaskoningDHV, The Netherlands

When imagining healthy environments for living, learning, and working it can be challenging to find the connections between home environments, healthcare, and how people move in their communities. Despite many innovations and technological advancements, less attention is given to the effects that calmer restorative environments can have on healthy human experience physically, psychologically and socially. Studies are surfacing that identify the link between feelings of isolation, anxiety and depression and the level of ambient stress caused by for example high traffic volumes, lack of green spaces, and few opportunities for social connection.

In this interactive session, we will examine these links from the perspectives of children, the elderly, women, disabled people, and other historically overlooked groups. How can bringing more social responsibility and kindness into infrastructure and mobility improve the human experience, contributing to healthier, more inclusive, and more kind spaces for citizens regardless of age, gender, physical ability, or economic means? Through an introductory presentation and new tools for measuring access as linked to wellbeing, Melissa Bruntlett, Esmee van Selst and Bige Tuncer will facilitate a discussion on the benefits made possible by thoughtfully designing and planning for mobility that enable a healthy combination of autonomy and social responsibility to our communities.

5

Citizen science, smart art & place making

5 Citizen science, smart art & place making: **conference paper**

Enhancing Public Familiarity in Semi-Public Spaces through Creative and Digital Placemaking: A Scoping Review of the Literature

Peyman Najafi[1*,2], Masi Mohammadi[1,2]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

*Corresponding author: Peyman Najafi (p.najafi@tue.nl)

Abstract: This scoping review examines the ways in which creative and digital placemaking can enhance public familiarity in semi-public spaces. Through a systematic analysis of 36 papers published between 2003 and 2023 from various databases, this review identifies key themes and concepts related to placemaking, public familiarity, and semi-public spaces. The analysis highlights the effectiveness of nine placemaking strategies and five smart technology-based solutions for improving public familiarity in semi-public spaces. Additionally, the paper identifies gaps in the current literature, emphasising the need for further research on the long-term impact of placemaking interventions and ethical considerations. This study has important implications for practitioners, policymakers, and researchers interested in enhancing public familiarity and social cohesion in urban semi-public environments through digital technologies. The paper concludes with recommendations for future research and practice, emphasising the significance of thorough evaluation and ethical considerations. In summary, this review provides valuable insights into the potential of creative and digital interventions to improve public familiarity in semi-public spaces.

Keywords: Creative placemaking; Digital placemaking; Public familiarity; Semi-public space; Smart technologies; Systematic literature review.

1. Introduction

Semi-public spaces are the heartbeat of cities, serving as the spaces that enable social interactions, community gatherings, and public familiarity [1], [2]. These spaces serve as connectors between private and public spheres, and are essential for creating livable, vibrant, and inclusive communities [3]. However, within the current urban neighbourhoods, many semi-public spaces are underutilised, neglected, or designed without consideration for the needs and preferences of their users [3]. As a result, these spaces may fail to foster a sense of community and belonging and may even engender feelings of anxiety and exclusion. To address these issues, creative and digital placemaking has emerged as a powerful tool for transforming semi-public spaces into dynamic and engaging environments that foster social cohesion, cultural exchange, and public familiarity [4].

Placemaking refers to a collaborative, people-centered approach to designing and activating public spaces that places the needs and aspirations of the people who use them at the centre of the process. It involves the careful curation of physical, social, and cultural enhancement of public familiarity in semi-public spaces, which is crucial for fostering a sense of community and belonging. Public familiarity refers to the sense of recognition and connection that people feel when they are in a familiar place [11]–[13]. This feeling is shaped by the physical, social, and cultural dimensions of the environment, as well as the experiences and memories associated with the place [14], [15]. Creative and digital placemaking strategies offer new opportunities to enhance public familiarity in semi-public spaces by integrating art, technology, and digital media into the physical, social, and cultural elements of placemaking. Creative placemaking can take many forms, including public art (e.g., [16]–[18]), temporary installations (e.g., [19]–[21], and community-driven projects [13], [22]. For example, murals or street art can transform the appearance of a neglected or underutilized space [23], while community-driven projects such as public gardens can bring together community members around a shared goal [24]. Digital placemaking, on the other hand, can use technology and digital media to enhance the physical and social environment of a semi-public space. Examples include the use of interactive displays (e.g., [8], [25], [26], augmented reality (e.g., [27], [28]), and gamification (e.g., [29]–[33]) to create new forms of engagement and participation.

Despite the growing interest in creative and digital placemaking, there remains a need for a comprehensive review of the literature to assess its impact on public familiarity in semi-public spaces. This scoping review aims to synthesize the existing knowledge on the theoretical and empirical underpinnings of creative and digital placemaking and its impact on public familiarity in semi-public spaces. The review draws upon a diverse range of literature sources, including peer-reviewed articles, books, reports, and case studies, to provide a comprehensive overview of the state of the art in this field.

The significance of this literature review lies in its potential to advance knowledge on the effectiveness of creative and digital placemaking strategies in enhancing public familiarity in semi-public spaces. This review will provide insights and recommendations for practitioners, policymakers, and researchers seeking to create more vibrant and engaging semi-public spaces. Furthermore, it can contribute to the development of best practices and guidelines for the use of creative and digital placemaking strategies in the design and activation of semi-public spaces.

The paper's outline is as follows: firstly, it provides a conceptual framework defining key concepts, including public familiarity and semi-public spaces, followed by an overview of creative and digital placemaking strategies. Secondly, it presents the methodology used to conduct the scoping review, including the search strategy, inclusion criteria, and data extraction process. Thirdly, this paper presents the results of the review, organized around themes that emerged from the literature, such as the theoretical and empirical underpinnings of creative and digital placemaking, the impact of these strategies on public familiarity in semi-public spaces, and the challenges and opportunities associated with their implementation. Fourthly, it discusses the implications of the review findings for urban designers, planners, policymakers, and other stakeholders involved in the creation and management of semi-public spaces, as well as identify gaps and limitations in the literature. Finally, this paper draws conclusions and provides recommendations for future research and practice, emphasizing the potential of creative and digital placemaking to transform semi-public spaces into more vibrant, engaging, and inclusive environments.

2. Background

2.1 Definition of public familiarity

The concept of public familiarity departs from Simmel's traditional view of the city as an anonymous space characterized by a blasé attitude [34], as well as from the urban village argument [35] that emphasizes the role of local social networks in shaping neighbourhood experiences [11]. Rather, public familiarity is a social space that is constructed in physical space through interactions in which individuals participate, as well as those that they observe. As Fischer (1982) suggests, public familiarity is often mistaken for private intimacy, and public impersonality is often perceived as private estrangement, but such public familiarity need not be directly tied to an individual's private life [36]. For example, a friendly greeter on the street may have few friends, while a reserved subway rider may have a thriving social life.

While more recent approaches to living in hyper-diverse neighbourhoods [37] focus on the presence of strangers and the processes of familiarization of people in co-presence, the social-psychological understanding of experiencing familiar strangers, as originally discussed by Milgram (1992) and developed by Ye (2019) as an individual's “special grammar of public spaces,” is less relevant to the current study [38], [39]. Instead, the concept of public familiarity as it relates to this study is characterized by loosely "thematized" knowledge and a mix of anonymity and intimacy [40].

Familiarity emerges from repetitive encounters in sites with accessibility to everyone who "conforms somewhat to the very generally expected patterns of action" [41]. This type of familiarity is rooted in the neighbourhood’s daily use and the interactions among inhabitants in public space, which may result in the sense of belonging to the territory that distinguishes it from stronger neighbourhood ties that are typically the focus of neighbourhood and community research [42]–[44].

Overall, public familiarity is widely understood as a result of the local socio-spatial experiences that individuals have as a result of their daily interactions in the neighbourhood’s public spaces.

It is a social space that is shaped by weak ties among neighbours and the feelings of familiarity and belonging that emerge from these contacts. Public familiarity is a principal factor in understanding the sense of territorial belonging that is experienced by individuals living in specific neighbourhoods.

2.2 Typology of semi-public spaces

Defining the typology of semi-public space can be challenging, as it is often specified by less obvious borders and characterized by social, rather than physical, boundaries. Semi-public spaces are typically outdoor areas that are widely accessible but more intimate and restricted than purely public spaces [3]. In residential areas, semi-public spaces are visually connected to surrounding buildings, providing a greater sense of responsibility and control over the space [1], [45]. The placement of semi-public spaces is critical, with activities and places to stay outside positioned directly in front of buildings and around entrance spaces to promote engagement.

According to Gehl (2001), it is crucial to provide an effortless way in and out of buildings, avoiding raised entry zones and changes in level that may hinder activities or create unwanted borders [3]. Creating places to sit, wait, and observe in the most obvious semi-public spaces can facilitate spontaneous meetings, promote safety through neighbourhood watching, and encourage engagement. Gehl also suggests the creation of semi-private spaces, such as porches and front yards, that smooth the transition between degrees of privacy and encourage community engagement without requiring immediate participation. It is important to note that opportunities to observe activities can also inspire further action.

The transition between private and semi-public zones is marked by diverse types of borders and edges. Walls and other impermeable surfaces are hard edges that do not allow for contact and interaction, while height differences and levels can disrupt easy connections, change views, and lessen sound relations [46]. Long distances and high speeds of movement can also inhibit contact and create borders. Planning and development of semi-public spaces, however, can serve as anchor points for activities and meetings, providing a sense of comfort, safety, and protection, and fostering community bonds [47]. Borders of these spaces should be inviting while clearly stating the rules of accessibility and usage possibilities. Planning should also include left-over spaces that can be given identity, connections, and transformed into places to stay and take care of [2], [48]. All these elements can encourage meeting, action, building of community, and a sense of belonging.

Overview of the different types of placemaking strategies, with a focus on creative and digital approaches

Placemaking is a fundamental process in creating vibrant and engaging (semi-)public spaces [49], [50]. The term "place-making" was first used in the 1960s by architects, urban planners, and designers who sought to renew public spaces, modify the image of cities, and develop tourism destinations [51], [52]. Since then, this approach has been studied under various

Keywords and variant spellings, such as "cultural mapping," "creative placemaking," and recently "digital placemaking" by scholars from different disciplines.

Creative placemaking involves the use of arts, culture, and creativity to enhance the interest of a place by incorporating digital technologies and narratives, such as through public art walks and mobile games [7]. In recent years, there has been a growing emphasis on more creative applications of "digital placemaking" that incorporate the combination of resources, meanings, and creativity to capture public attention through narratives (e.g., [32], [33], [53], [54]).

For instance, the concept of "cultural mapping" is a methodological tool used in urban planning, cultural sustainability, and community development to highlight local stories, practices, relationships, memories, and rituals that make places meaningful locations [55]. These thematic foci have converged in the form of interactive digital narratives, such as serious games, interactive documentaries, and transmedia stories, to provide "edutainment" experiences where digital users are educated in an entertaining manner to maintain their interest.

Combined, creative and digital placemaking approaches can produce dynamic and engaging semi-public spaces that foster social interaction, community building, and a sense of place [9]. The use of digital technologies can also help bridge the gap between physical and virtual spaces, enhancing the connection between people and their environment [53].

While creative and digital placemaking approaches are gaining recognition as effective ways to transform semi-public spaces, it is crucial to acknowledge that they are not universally applicable. The success of placemaking strategies depends on a deep understanding of the local context, including the social, cultural, and economic dynamics of the area [4], [49]. Additionally, any placemaking approach should be developed through a participatory process involving the community in the strategy's design, implementation, and evaluation of the strategy. This collaborative process ensures that the placemaking strategy aligns with the community's needs and values and fosters a sense of ownership and belonging among residents, visitors, and other stakeholders [46]. By engaging the community in placemaking initiatives, it is possible to create more inclusive, responsive, and sustainable public spaces that promote social interaction and enhance public familiarity.

In the next section, we will provide a scoping review of the literature to examine the effectiveness of various strategies employed in creative and digital placemaking to foster public familiarity and promote social interaction in semi-public spaces thus far.

3. Methods

This study employed a scoping review methodology to identify and analyze existing literature (published between 2003 and January 2023) on creative and digital placemaking strategies that enhance public familiarity in semi-public spaces. A scoping review is a systematic review that aims to map and analyze the literature on a specific topic or research question, identifying key concepts and themes in the process [56]. This scoping review synthesizes diverse literature sources, such as peer-reviewed articles, books, reports, and case studies. Through this approach, it aims to provide a comprehensive understanding of the state of the art in the field of creative and digital placemaking, including theoretical and empirical underpinnings, as well as challenges and opportunities associated with their implementation.

The search strategy for this scoping review consisted of multiple stages. Firstly, a broad keyword search was conducted using online academic databases such as Google Scholar, Scopus, PubMed, and Web of Science. The search terms used included variations of "creative placemaking", "digital placemaking", "public art", "urban design", "community engagement", "place identity", "semi-public spaces" and other related terms.

Following the initial search, inclusion and exclusion criteria were used to filter the results. Inclusion criteria included peer-reviewed journal articles, books, and book chapters that discussed creative and digital placemaking strategies and their effectiveness in enhancing public familiarity in semi-public spaces. Exclusion criteria included non-English language publications, grey literature, and publications that focused solely on private or completely public spaces. A total of 36 studies met our inclusion criteria, which were then analyzed and synthesized (Table 1).

To assist with our systematic literature review, we employed ChatGPT, a state-of-the-art natural language processing tool developed by OpenAI [57]. ChatGPT was used to generate summaries and insights from large volumes of text quickly, allowing us to identify key concepts and themes within the literature that might have been missed through manual review alone. By analyzing the summaries generated by ChatGPT, we were able to quickly identify commonalities and differences between the papers and develop a better understanding of the overall trends and patterns within the literature [58]– [60].

However, we acknowledge that ChatGPT may not be able to capture the nuances and complexities of certain types of text, and that its summaries are subject to biases based on the training data it has been exposed to. Given these limitations, and since this review is one of the first to use ChatGPT as an analytical tool, we used it in conjunction with manual review to ensure accuracy and completeness.

The identified themes and concepts were organized into a table that provided a brief description of each category, as well as the author(s) and year(s) in which they were mentioned. The findings of the review were synthesized into a comprehensive analysis of the effectiveness of different placemaking strategies in enhancing public familiarity in semi-public spaces, and a discussion of the factors that contribute to success. This analysis was based on the key themes and concepts identified in the literature and was informed by the theoretical frameworks and models used to understand creative and digital placemaking in semi-public spaces. The methodological framework used to select and review the relevant papers in this study is illustrated in Figure 1.

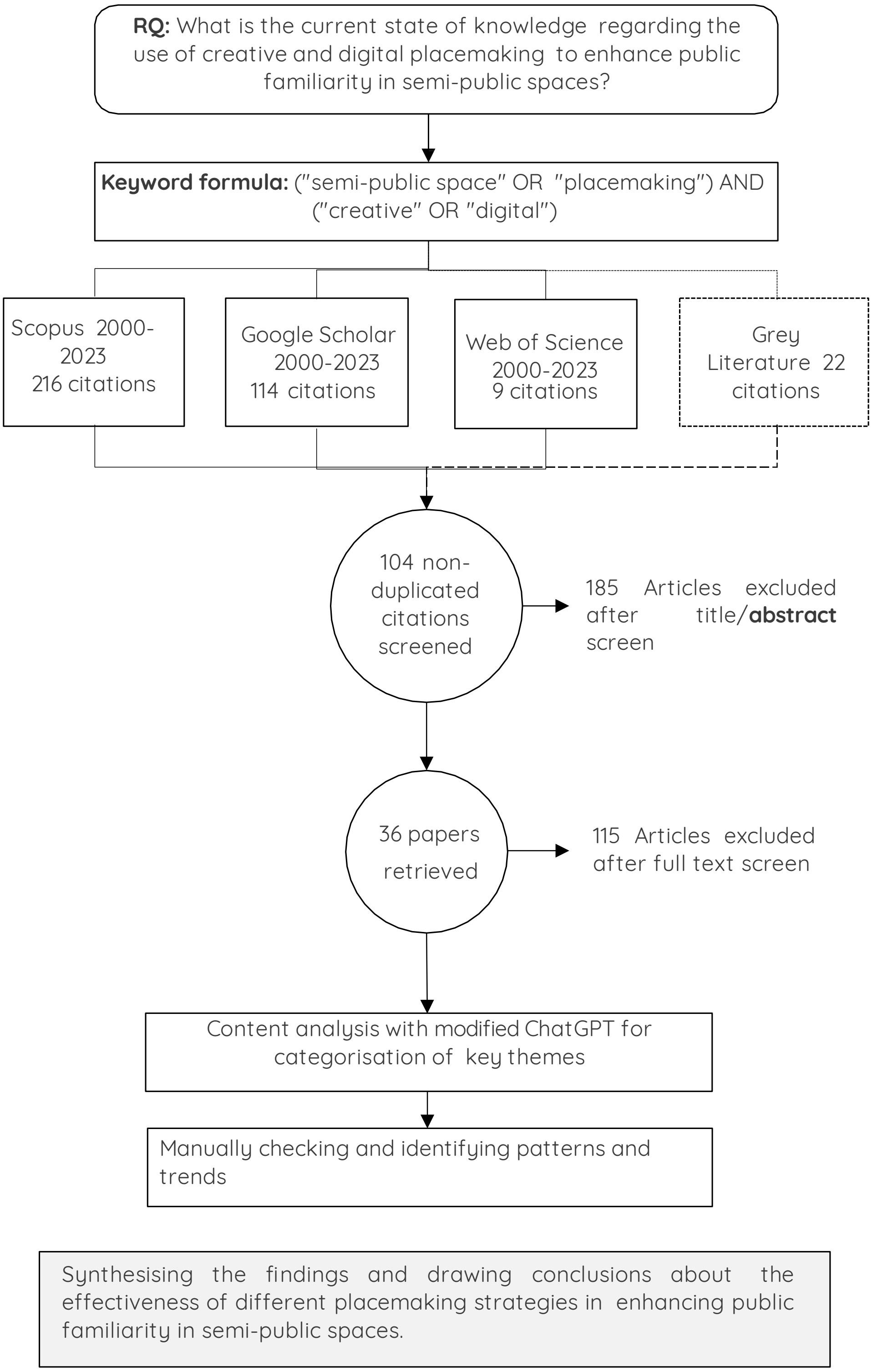


Figure 1. Selected paper for reviews using PRISMA

4. Results and analysis

Summary of the literature reviewed and the key themes found

Placemaking, particularly in the form of creative and digital placemaking, is a rapidly growing field that offers innovative and exciting possibilities for enhancing public familiarity in semi-public spaces. Existing literature on this topic identifies several strategies and concepts related to creative and digital placemaking to enhance public familiarity in semi-public space, which can be classified into distinct categories. Table 1, summarizes the distinct categories of placemaking strategies and their associated explanations, and authors who have mentioned or cited the category.

Table 1. The categories of ideas and concepts related to enhancing public familiarity in semi-public spaces through creative and digital placemaking

Category	Explanation	Reference(s)
Trans-scale placemaking, Digital media and technology	includes concepts and ideas related to the use of extended-reality or cross-reality technologies to evoke a stronger sense of place. Also, it includes the use of digital media and technology in creative placemaking. Virtual and augmented reality, location-based games, and digital heritage narratives are some examples of such concepts.	[8], [25], [27], [29], [53], [61]–[65]
Public art and culture	includes ideas and concepts related to the use of public art and culture as a means of placemaking. Murals, street performances, and festivals are some examples of such concepts. Public art and culture can be used to create a sense of place, attract tourism, and promote a more vibrant and engaging public space.	[6], [16], [18], [23], [54], [66]
Embedded artists	Embedded artists in government can incorporate artistic methods and perspectives in non-art contexts, often in collaboration with government staff, leading to cross-sector collaboration and idea generation. Void Deck Galleries in Singapore can serve as a case study for examining the relationships between the state, artists, and local communities in the context of creative placemaking and community art.	[67]–[70]
Community engagement and participation	involves involving the community in the design and planning of public spaces to ensure that they meet the needs and desires of the people who use them. Co-design and participatory tactics are some examples of such concepts.	[13], [17], [53], [71], [72]
Place identity and heritage	includes ideas and concepts related to the use of heritage and identity to create a sense of place. Preserving heritage public spaces and integrating cultural heritage into placemaking are some examples of such concepts.	[6], [42], [62], [73]
Aesthetics and design	concepts and ideas related to the design of physical and digital spaces. Multisensory ambiance, design patterns, and environmental graphic design are some examples of such concepts.	[74], [75]
Community development and well-being	Impact of community arts centres on social cohesion, use of creative placemaking in informal care for older adults	[4], [12], [63]
Bottom-up placemaking	includes concepts and ideas related to bottom-up placemaking, such as the everyday creative practice of eyebrow grooming and the use of irregular yet civic-minded do-it- yourself urban design projects.	[76]
Temporary installations and events	Temporary installations and events can also be used to activate underutilized areas, encourage community engagement, and test new ideas. For example, pop-up installations, festivals, and exhibitions can be used to create a buzz and generate interest in a place, while also providing opportunities for experimentation and innovation.	[19]–[21], [65], [71], [77], [78]

Summary of the literature on the use of digital instruments to enhance public familiarity in semi-public spaces

Our review reveals that the rise of digital technologies, such as social media, mobile applications, and interactive installations, has transformed the way people connect and communicate, and these technologies have been explored as potential instruments for enhancing public familiarity in semi-public spaces. Table 2 illustrates the existing literature on the employment of these instruments in semi-public spaces to promote public familiarity. We will summarise the key findings and challenges that have emerged from this review.

Table 2. The use of smart technology to enhance public familiarity in semi-public spaces

Technology	Benefits	Mechanisms	Conditions for Success	Ethical Considerations
Social media platforms	- Effective tool for building social capital in public spaces. - Providing a platform for sharing information, building trust, and forming new relationships. - Promoting social connections among community members.	Facilitating the sharing of information, building of trust and forming of relationships	Accessing to social media, familiarity with digital devices and technology, and protection of privacy and prevention of cyberbullying	Risk of cyberbullying, erosion of privacy, and reinforcement of existing social hierarchies, exclusion of groups without access to technology
Mobile applications	- Facilitating communication and cooperation among park visitors. - Effective in fostering a sense of community and promoting collective decision-making. - Effective in building social connections and reducing traffic congestion.	Facilitating communication and cooperation, and providing information for collective decision-making	Access to mobile applications, digital literacy, and compatibility with mobile devices	Association with social isolation, lack of face-to-face communication, exclusion of groups without access to technology, and potential for privacy violations
Interactive installations	- Effective in fostering social connections and building a sense of community. - Providing real-time environmental information to community members. - Encouraging	Encouraging social interaction and communication through interactive experiences	Affective design, accessibility, and ease of use of the interactive installations	Potential for exclusion, reinforcement of existing power imbalances, and ethical implications for privacy, safety, and data protection

Technology	Benefits	Mechanisms	Conditions for Success	Ethical Considerations
	collaboration and play among park visitors			
VR / AR	- Effective in promoting community engagement and a sense of place by allowing community members to explore the history of their neighbourhood. - Effective in supporting local economic development by providing information about local businesses and services.	Promoting immersive experiences and information-sharing for community engagement and development	Access to virtual or augmented reality systems, affordability, and compatibility with digital devices	Ethical considerations for exclusions, privacy and data protection
IoT / IoB	- Providing real-time information to reduce traffic congestion and promote cooperation among drivers. - Effective in promoting community engagement and awareness by providing environmental information to community members.	Providing real-time information to facilitate cooperation and awareness	Accessing to IoT-based systems, technological expertise, and privacy and security protections	Ethical implications for privacy, data protection, and the potential for exclusions and digital divides

5. Discussion

This scoping review has explored the literature on the use of creative and digital placemaking to enhance public familiarity in semi-public spaces. Our findings underline that there is a growing interest in the potential of creative and digital placemaking to transform semi-public spaces into more engaging and inclusive public spaces. The review has highlighted the strategies that have been used to achieve this goal (Table 1). Also, it has identified various influential factors that contribute to the success of these strategies (Table 2).

One of the key findings of this review is the potential of digital technologies to enhance public familiarity in semi-public spaces. Digital placemaking has the potential to engage diverse communities and promote social interaction. Examples of digital placemaking initiatives include interactive installations, augmented reality experiences, and mobile apps that provide information and facilitate communication between community members. Digital placemaking can also provide opportunities for data collection and analysis, which can inform decision-making and enhance the effectiveness of placemaking initiatives.

The use of digital technologies in placemaking is intricately linked to the emerging field of the Internet of Things (IoT) and the Internet of Behaviours (IoB). IoB is a subset of IoT that involves the collection, analysis, and use of data from various sources, including sensors, social media, and other digital platforms, to understand and influence human behaviour [4], [53]. The potential of IoB in placemaking is significant, as it can provide insights into how people interact with the built environment and inform the design of more effective and engaging public spaces. For example, IoB can be used to monitor foot traffic, analyze user behaviour, and provide real-time feedback to inform the design and management of public spaces.

Despite the potential benefits, the review also identifies several limitations and gaps in the literature. One of the limitations is the lack of a systematized approach for evaluating the effectiveness of placemaking interventions. Additionally, most studies focus on short-term outcomes, with few studies investigating the long-term impacts of placemaking interventions. Furthermore, this review raises several implications and ethical considerations for practitioners, policymakers, and researchers:

1) Privacy concerns: The use of smart technologies in semi-public spaces can raise concerns about privacy and data security. For example, the collection and storage of personal data may be viewed as intrusive or a potential threat to the privacy of community members. There is a need to consider how data will be collected, stored, and used, and to ensure that appropriate safeguards are in place to protect the privacy and security of community members. This may include adopting data protection policies and procedures, limiting the collection and use of personal data, and ensuring that community members are fully informed about the use of smart technologies in the space.

2) Equity concerns: The use of smart technologies in semi-public spaces can also raise concerns about social equity. For example, the cost of implementing and maintaining smart technologies may create inequities between communities that have access to these technologies and those that do not. There is a need to ensure that the use of smart technologies in semi-public spaces is accessible and inclusive for all community members, regardless of socioeconomic status. This can include developing strategies to ensure that the cost of implementing and maintaining smart technologies is not prohibitive, and considering how the needs and preferences of marginalised or disadvantaged groups can be taken into account.

3) Technological limitations: While smart technologies hold great promise, there are also limitations to their effectiveness. For example, the accuracy of sensors can be affected by environmental factors, and the effectiveness of smart technologies may be limited by the physical layout of the space in which they are implemented. There is a need to consider the limitations of smart technologies when designing and implementing these technologies, and to develop strategies for overcoming these limitations. This may include adopting a multi-modal approach to data collection, such as using a combination of sensors and user-generated data, or developing algorithms that can account for environmental factors.

4) Community engagement: The success of smart technologies in enhancing social connections in semi-public spaces is heavily dependent on community engagement and support. There is a need to involve community members in the design and implementation of smart technologies, and to ensure that their needs and preferences are taken into account. Additionally, community members should be involved in the monitoring and evaluation of these technologies, to ensure that they are meeting the needs of the community. This may include holding community workshops or consultations to gather feedback and input, and establishing community committees or groups to oversee the implementation and evaluation of smart technologies.

5) Maintenance and upkeep: Smart technologies require ongoing maintenance and upkeep to ensure their effectiveness. There is a need to consider the resources and expertise required to maintain and update smart technologies, and to develop strategies for ensuring that these technologies remain effective over time. This may include developing a maintenance plan or schedule, training staff or community members to conduct maintenance and repairs, and ensuring that sufficient resources are allocated to the ongoing upkeep of smart technologies.

6) Legal and regulatory considerations: The use of smart technologies in semi-public spaces may also raise legal and regulatory considerations. For example, there may be regulations or guidelines in place that restrict the collection or use of personal data, or that require the implementation of specific security measures. There is a need to ensure that the use of smart technologies in semi-public spaces is in compliance with applicable laws and regulations, and to ensure that any potential legal or regulatory issues are identified and addressed.

7) Social and cultural factors: *Smart* technologies are embedded in social and cultural contexts that can shape their impact on social connections in semi-public spaces. There is a need to consider the social and cultural factors that may influence the use and effectiveness of smart technologies in different contexts. For example, cultural norms and values may affect how community members perceive and interact with smart technologies, and social dynamics within the community may impact the uptake and acceptance of these technologies. There is a need to consider the social and cultural factors that may influence the use and effectiveness of smart technologies in different contexts, and to develop strategies for adapting these technologies to meet the needs and preferences of diverse communities.

8) Ethical considerations: The use of smart technologies in semi-public spaces raises important ethical considerations, such as the potential for these technologies to reinforce existing power dynamics or to create new forms of social exclusion. There is a need to consider the ethical implications of the use of smart technologies in semi-public spaces, and to ensure that these technologies are designed and implemented in ways that are consistent with ethical principles and values. This may include adopting ethical frameworks or guidelines to guide the development and implementation of smart technologies, and ensuring that the needs and preferences of diverse user groups are taken into account.

Recommendations for Future Research and Practice

This scoping review identified gaps in the literature, suggesting the need for further research and practice in this area.

One key area for future research is the development of more rigorous evaluation methods. While some studies have attempted to measure the impact of creative and digital placemaking on public familiarity, there is a need for more robust evaluation methods that can measure the impact on a range of outcomes, such as social cohesion and community well-being. In addition, future research should seek to understand the factors that contribute to the success or failure of creative and digital placemaking interventions, including the role of community engagement and the importance of context.

Another major area for future research is the exploration of the potential of IoB technologies in creative and digital placemaking. While some studies have highlighted the potential of these technologies, there is a need for more research that can demonstrate the impact of IoB technologies on public familiarity and other outcomes. In addition, future research should explore the ethical considerations associated with the use of these technologies in creative and digital placemaking.

Finally, practitioners and policymakers should continue to prioritise the inclusion of long-time residents and other marginalized groups in the planning and implementation of creative and digital placemaking interventions. This can help to ensure that the benefits of these interventions are distributed equitably and that unintended consequences are avoided. In addition, practitioners and policymakers should work to develop more inclusive and participatory processes for the planning and implementation of creative and digital placemaking interventions.

6. Conclusion

This scoping review has provided a comprehensive overview of the literature on enhancing public familiarity in semi-public spaces through creative and digital placemaking. The findings suggest that creative and digital placemaking interventions can effectively enhance public familiarity in semi-public spaces through various strategies, such as providing amenities and social gathering spaces, promoting local culture and identity, and utilising technology to facilitate communication and interaction among individuals.

However, the review also highlights the need for more rigorous evaluation and reporting of the effectiveness of placemaking interventions in enhancing public familiarity. Furthermore, the review reveals the limited attention paid to ethical considerations in placemaking, such as issues of inclusivity, accessibility, and privacy, which should be considered when designing and implementing placemaking interventions.

The implications of this study for practitioners, policymakers, and researchers are significant. Practitioners and policymakers can use the findings of this study to guide the design and implementation of effective placemaking interventions that foster public familiarity and enhance the liveability of cities. Researchers can build on the gaps and limitations identified in this study to develop more rigorous and comprehensive evaluations of placemaking interventions.

In conclusion, this scoping review underscores the importance of creative and digital placemaking in enhancing public familiarity in semi-public spaces. While there is a need for more research on the effectiveness of placemaking interventions and the ethical considerations associated with them, the findings of this study offer valuable insights for creating more livable and inclusive cities through effective placemaking interventions.

References

[1] M. Carmona, C. de Magalhães, and L. Hammond, Eds., Public Space: The Management Dimension. London: Routledge, 2008. doi: 10.4324/9780203927229.

[2] M. Orhan, "The Use of Semi-public Spaces as Urban Space and Evaluation in Terms of Urban Space Quality," in Urban and Transit Planning, Cham, 2022, pp. 203–212. doi: 10.1007/978-3-030- 97046-8_16.

[3] J. Gehl, "Life between buildings/Gehl J." Copenhagen: The Danish Architectural Press, 2001.

[4] P. Najafi, M. Mohammadi, P. M. Le Blanc, and P. van Wesemael, "Insights into placemaking, senior people, and digital technology: a systematic quantitative review," J. Urban. Int. Res. Placemaking Urban Sustain., vol. 0, no. 0, pp. 1–30, May 2022, doi: 10.1080/17549175.2022.2076721.

[5] C. Courage and A. McKeown, Eds., Creative Placemaking: Research, Theory and Practice. London: Routledge, 2018. doi: 10.4324/9781315104607.

[6] J. L. Daniel and M. Kim, "Creative Placemaking: Creating Change by Building Partnerships," J. Public Nonprofit Aff., vol. 6, no. 1, Art. no. 1, Apr. 2020, doi: 10.20899/jpna.6.1.96-110.

[7] S. Wilbur, "It's about Time Creative placemaking and performance analytics," Perform. Res., vol. 20, no. 4, pp. 96–103, Jul. 2015, doi: 10.1080/13528165.2015.1071046.

[8] J. Hardley and I. Richardson, "Digital placemaking and networked corporeality: Embodied mobile media practices in domestic space during Covid-19," Convergence, vol. 27, no. 3, pp. 625–636, Jun. 2021, doi: 10.1177/1354856520979963.

[9] A. Sharma and R. K. Jaggi, "Reconceptualising Digital Placemaking: A Netnographic Study from the State of Uttarakhand, India," J. Creat. Commun., p. 09732586221088137, Apr. 2022, doi: 10.1177/09732586221088137.

[10] M. Tomitsch, I. McArthur, M. H. Haeusler, and M. Foth, "The Role of Digital Screens in Urban Life: New Opportunities for Placemaking," in Citizen's Right to the Digital City: Urban Interfaces, Activism, and Placemaking, M. Foth, M. Brynskov, and T. Ojala, Eds. Singapore: Springer, 2015, pp. 37–54. doi: 10.1007/978-981-287-919-6_3.

[11] T. Blokland and J. Nast, "From Public Familiarity to Comfort Zone: The Relevance of Absent Ties for Belonging in Berlin's Mixed Neighbourhoods," Int. J. Urban Reg. Res., vol. 38, no. 4, pp. 1142– 11 59, 2014, doi: 10.1111/1468-2427.12126.

[12] A. Nagel, K. Voigt, B. Meyer, H. Glaesmer, B. Löwe, and E. Brähler, "Public familiarity with the terms Somatoform disorder and functional disorder in Germany: Results from a representative population survey," Prim. Care Companion J. Clin. Psychiatry, vol. 14, no. 1, 2012, doi: 10.4088/PCC.11m01209.

[13] F. Link, A. Señoret, and F. Valenzuela, "From Community to Public Familiarity: Neighborhood, Sociability, and Belonging in the Neoliberal City," Urban Aff. Rev., vol. 58, no. 4, pp. 960–995, 2022, doi: 10.1177/10780874211021512.

[14] D. M. Spotts and D. J. Stynes, "Measuring the public's familiarity with recreation areas.," J. Leis. Res., vol. 17, no. 4, pp. 253–265, 1985, doi: 10.1080/00222216.1985.11969636.

[15] M. Saengpattrachai, D. Srinualta, N. Lorlertratna, E. Pradermduzzadeeporn, and F. Poonpol, "Public familiarity with, knowledge of, and predictors of negative attitudes toward epilepsy in Thailand," Epilepsy Behav., vol. 17, no. 4, pp. 497–505, 2010, doi: 10.1016/j.yebeh.2010.01.164.

[16] V. Lovell, "Artists and the Public Spaces of the City," Built Environ., vol. 46, no. 2, pp. 54–68, May 2020, doi: 10.2148/benv.46.2.214.

[17] A. J. Ashley, "The Micropolitics of Performance: Pop-up Art as a Complementary Method for Civic Engagement and Public Participation," J. Plan. Educ. Res., vol. 41, no. 2, pp. 173–187, Jun. 2021, doi: 10.1177/0739456X18779428.

[18] T. Matthews and S. Gadaloff, "Public art for placemaking and urban renewal: Insights from three regional Australian cities," Cities, vol. 127, p. 103747, Aug. 2022, doi: 10.1016/j.cities.2022.103747.

[19] T. Beer, L. Fu, and C. Hernández-Santín, "Scenographer as placemaker: co-creating communities through The Living Stage NYC," Theatre Perform. Des., vol. 4, no. 4, pp. 342–363, Oct. 2018, doi: 10.1080/23322551.2018.1556014.

[20] N. Karachalis, "Temporary Use as a Participatory Placemaking Tool to Support Cultural Initiatives and Its Connection to City Marketing Strategies—The Case of Athens," Sustainability, vol. 13, no. 4, Art. no. 4, Jan. 2021, doi: 10.3390/su13041652.

[21] M. Koiva, "Inventing Sacred Places: Wooden Sculptures and Placemaking of Contemporary Landscape," Yearb. Balk. Balt. Stud., vol. 1, pp. 61–76, Dec. 2018, doi: 10.7592/YBBS1.05.

[22] J. J. Crisman, "Evaluating values in creative placemaking: The arts as community development in the NEA's Our Town program," J. Urban Aff., vol. 44, no. 4–5, pp. 708–726, May 2022, doi: 10.1080/07352166.2021.1890607.

[23] L. S. Furtado and J. M. Payne, "Inclusive Creative Placemaking Through Participatory Mural Design in Springfield (MA)," J. Am. Plann. Assoc., vol. 0, no. 0, pp. 1–14, Jul. 2022, doi: 10.1080/01944363.2022.2083008.

[24] J. Lindemann, "Gardens and Green Spaces: placemaking and Black entrepreneurialism in Cleveland, Ohio," Agric. Hum. Values, vol. 36, no. 4, pp. 867–878, Dec. 2019, doi: 10.1007/s10460-019-09947-w.

[25] M. Tomitsch, "12 - Interactive media facades—research prototypes, application areas and future directions," in Rethinking Building Skins, E. Gasparri, A. Brambilla, G. Lobaccaro, F. Goia, A. Andaloro, and A. Sangiorgio, Eds. Woodhead Publishing, 2022, pp. 313–337. doi: 10.1016/B978-0-12-822477-9.00019-X.

[26] I. Paraschivoiu, "Affective Interaction in UrbanIxD: Designing for the Lived Urban Experience," in Designing Interactive Systems Conference, New York, NY, USA, Jun. 2022, pp. 24–27. doi: 10.1145/3532107.3532877.

[27] I. Gwilt, A. Davis, J. Mignone, R. T. Smith, and A. Chua, "Augmenting Environmental Graphics in Healthcare Spaces," in Augmented Reality Art: From an Emerging Technology to a Novel Creative Medium, V. Geroimenko, Ed. Cham: Springer International Publishing, 2022, pp. 191–208. doi: 10.1007/978-3-030-96863- 2_10.

[28] T. F. Tengku Anuar et al., "Augmented Reality Street Art (ARSA) Model to Revitalize Deserted Alley in Kota Bharu, Kelantan Towards Shared Prosperity Vision 2030: A Systematic Literature Review," in Financial Technology (FinTech), Entrepreneurship, and Business Development, Cham, 2022, pp. 749–765. doi: 10.1007/978- 3-031-08087-6_52.

[29] T. Innocent, "Play about Place: Placemaking in location-based game design," in Proceedings of the 4th Media Architecture Biennale Conference, New York, NY, USA, Nov. 2018, pp. 137–143. doi: 10.1145/3284389.3284493.

[30] A. G. Prawata, "Playful urban intervention as creative placemaking strategy in Jakarta," IOP Conf. Ser. Earth Environ. Sci., vol. 426, no. 1, p. 012083, Feb. 2020, doi: 10.1088/1755-1315/426/1/012083.

[31] A. Low, J. Turner, and M. Foth, "Pla(y)cemaking With Care: Locative Mobile Games as Agents of Place Cultivation," in Proceedings of the 25th International Academic Mindtrek Conference, New York, NY, USA, Nov. 2022, pp. 135–146. doi: 10.1145/3569219.3569311.

[32] C. Pang, R. Pan, S. Wong, C. Neustaedter, and Y. Wu, "The Design of a Location-Based Transit Game for Digital Placemaking," in Conference Companion Publication of the 2020 on Computer Supported Cooperative Work and Social Computing, New York, NY, USA, Oct. 2020, pp. 47–51. doi: 10.1145/3406865.3418565.

[33] C. Pang, C. Neustaedter, K. Moffatt, K. Hennessy, and R. Pan, "The role of a location-based city exploration game in digital placemaking," Behav. Inf. Technol., vol. 39, no. 6, pp. 624–647, Jun. 2020, doi: 10.1080/0144929X.2019.1697899.

[34] G. Simmel, "The Metropolis and Mental Life," GEORG SIMMEL.

[35] L. Berkowitz, "Book Review: The Urban Villagers: Group and Class in the Life of Italian-Americans," Soc. Casework, vol. 44, no. 7, pp. 411–411, Jul. 1963, doi: 10.1177/104438946304400707.

[36] C. S. Fischer, To Dwell Among Friends: Personal Networks in Town and City. University of Chicago Press, 1982.

[37] S. Vertovec, Ed., Diversities Old and New. London: Palgrave Macmillan UK, 2015. doi: 10.1057/9781137495488.

[38] S. Milgram, The individual in a social world: Essays and experiments, 2nd ed. New York, NY, England: Mcgraw-Hill Book Company, 1992, pp. xxxiii, 345.

[39] J. Ye and A. Wafer, Rooms without walls: Cards and clusters. Palgrave Macmillan, 2015, pp. 201–207. Accessed: Feb. 28, 2023. [Online]. Available: http://www.palgrave.com/us/book/9781137495471

[40] M. Felder, "Familiarity as a Practical Sense of Place," Sociol. Theory, vol. 39, no. 3, pp. 180–199, Sep. 2021, doi: 10.1177/07352751211037724.

[41] R. M. Silverman, "Networked Urbanism: Social Capital in the City," Contemp. Sociol., vol. 38, no. 3, pp. 283–284, May 2009.

[42] T. Blokland, R. Vief, D. Krüger, and H. Schultze, "Roots and routes in neighbourhoods. Length of residence, belonging and public familiarity in Berlin, Germany," Urban Stud., 2022, doi: 10.1177/00420980221136960.

[43] A. M. Guest and S. K. Wierzbicki, "Social Ties at the Neighborhood Level: Two Decades of GSS Evidence," Urban Aff. Rev., vol. 35, no. 1, pp. 92–111, Sep. 1999, doi: 10.1177/10780879922184301.

[44] J. A. Carrasco, E. J. Miller, and B. Wellman, "How Far and with Whom Do People Socialize?: Empirical Evidence About Distance Between Social Network Members," Transp. Res. Rec., vol. 2076, no. 1, pp. 114–122, Jan. 2008, doi: 10.3141/2076-13.

[45] M. Carmona, Public places urban spaces: The dimensions of urban design. Routledge, 2021.

[46] "An Idea Book for Placemaking: Semi Public Zone." https://www.pps.org/article/semi-public-zone (accessed Feb. 28, 2023).

[47] K. N. Hampton and N. Gupta, "Community and social interaction in the wireless city: wi-fi use in public and semi-public spaces," New Media Soc., vol. 10, no. 6, pp. 831–850, Dec. 2008, doi: 10.1177/1461444808096247.

[48] S. Nissen, "Urban Transformation From Public and Private Space to Spaces of Hybrid Character," Sociol. Časopis Czech Sociol. Rev., vol. 44, no. 06, pp. 1129–1149, 2008.

[49] M. A. Wyckoff, "Definition of placemaking: Four different types," Plan. Zoning News, vol. 32, no. 3, p. 1, 2014.

[50] P. Najafi, M. Mohammadi, P. M. Le Blance, and P. van Wesemael, "Intelligent Placemaking, Bringing Digital Twin and Virtual Reality to Shape a Healthy Ageing Neighbourhood: The Blue Zones' Case and User Experience Study." Rochester, NY, Feb. 10, 2022. doi: 10.2139/ssrn.4031420.

[51] J. Jacobs, The Death and Life of Great American Cities, Reissue edition. New York: Vintage, 1992.

[52] P. Najafi, M. Mohammadi, P. M. Le Blanc, and P. Van Wesemael, "Experimenting a Healthy Ageing Community in Immersive Virtual Reality Environment: The Case of World's Longest-lived Populations," in 2021 17th International Conference on Intelligent Environments (IE), Jun. 2021, pp. 1–5. doi: 10.1109/IE51775.2021.9486595.

[53] P. Najafi, M. Mohammadi, P. van Wesemael, and P. M. Le Blanc, "A user-centred virtual city information model for inclusive community design: State-of-art," Cities, vol. 134, p. 104203, Mar. 2023, doi: 10.1016/j.cities.2023.104203.

[54] T. C. Chang, "Van Gogh in the Neighborhood: Creative Placemaking and Community Art in Singapore," Ann. Am. Assoc. Geogr., vol. 112, no. 5, pp. 1500–1517, Jul. 2022, doi: 10.1080/24694452.2021.1977108.

[55] C. G. Loh, A. J. Ashley, R. Kim, L. Durham, and K. Bubb, "Placemaking in Practice: Municipal Arts and Cultural Plans' Approaches to Placemaking and Creative Placemaking," J. Plan. Educ. Res., p. 0739456X221100503, Jul. 2022, doi: 10.1177/0739456X221100503.

[56] D. Levac, H. Colquhoun, and K. K. O'Brien, "Scoping studies: advancing the methodology," Implement. Sci., vol. 5, pp. 1–9, 2010.

[57] E. A. van Dis, J. Bollen, W. Zuidema, R. van Rooij, and C. L. Bockting, "ChatGPT: five priorities for research," Nature, vol. 614, no. 7947, pp. 224–226, 2023.

[58] S. Biswas, "ChatGPT and the future of medical writing," Radiology. Radiological Society of North America, p. 223312, 2023.

[59] M. Dowling and B. Lucey, "ChatGPT for (finance) research: The Bananarama conjecture," Finance Res. Lett., p. 103662, 2023.

[60] B. D. Lund and T. Wang, "Chatting about ChatGPT: how may AI and GPT impact academia and libraries?," Libr. Hi Tech News, 2023.

[61] G. Neff, "The Changing Place of Cultural Production: The Location of Social Networks in a Digital Media Industry," Ann. Am. Acad. Pol. Soc. Sci., vol. 597, no. 1, pp. 134–152, Jan. 2005, doi: 10.1177/0002716204270505.

[62] A. Sebastiani, "Digital Artifacts and Landscapes. Experimenting with Placemaking at the Impero Project," Heritage, vol. 4, no. 1, Art. no. 1, Mar. 2021, doi: 10.3390/heritage4010018.

[63] B. Stokes, F. Bar, K. Baumann, B. Caldwell, and A. Schrock, “Urban furniture in digital placemaking: Adapting a storytelling payphone across Los Angeles,” Convergence, vol. 27, no. 3, pp. 711–726, Jun. 2021, doi: 10.1177/1354856521999181.

[64] M. Rzeszewski and J. Naji, “Literary placemaking and narrative immersion in extended reality virtual geographic environments,” Int.J. Digit. Earth, vol. 15, no. 1, pp. 853–867, Dec. 2022, doi: 10.1080/17538947.2022.2061619.

[65] G. S. Cornelio and E. Ardévol, “Practices of place-making through locative media artworks,” vol. 36, no. 3, pp. 313–333, Sep. 2011, doi: 10.1515/comm.2011.016.

[66] G. Richards, “Creativity and tourism: The State of the Art,” Ann. Tour. Res., vol. 38, no. 4, pp. 1225–1253, Oct. 2011, doi: 10.1016/j.annals.2011.07.008.

[67] C. Grodach, N. Foster, and J. Murdoch, “Gentrification and the Artistic Dividend: The Role of the Arts in Neighborhood Change,”J. Am. Plann. Assoc., vol. 80, no. 1, pp. 21–35, Jan. 2014, doi: 10.1080/01944363.2014.928584.

[68] M. A. Rich, “‘Artists are a tool for gentrification’: maintaining artists and creative production in arts districts,” Int. J. Cult. Policy, vol. 25, no. 6, pp. 727–742, Sep. 2019, doi: 10.1080/10286632.2017.1372754.

[69] A. Shkuda, “The Artist as Developer and Advocate: Real Estate and Public Policy in SoHo, New York,” J. Urban Hist., vol. 41, no. 6, pp. 999–1016, Nov. 2015, doi: 10.1177/0096144215602008.

[70] J. K. Taylor, “Art Practice as Policy Practice: Framing the Work of Artists Embedded in Government,” J. Arts Manag. Law Soc., vol. 51, no. 4, pp. 224–237, Jul. 2021, doi: 10.1080/10632921.2021.1925193.

[71] J. Fredericks, M. Tomitsch, L. Hespanhol, and I. McArthur, “Digital Pop-Up: Investigating Bespoke Community Engagement in Public Spaces,” in Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction, New York, NY, USA, Dec. 2015, pp. 634–642. doi: 10.1145/2838739.2838759.

[72] M. G. Hunter, A. Soro, R. A. Brown, J. Harman, and T. Yigitcanlar, “Augmenting Community Engagement in City 4.0: Considerations for Digital Agency in Urban Public Space,” Sustainability, vol. 14, no. 16, Art. no. 16, Jan. 2022, doi: 10.3390/su14169803.

[73] M. M. Rashid, C. K. Khoo, S. Kaljevic, and S. Pancholi, “Presence of the Past: Digital Narrative of the Dennys Lascelles Concrete Wool Store; Geelong, Australia,” Remote Sens., vol. 13, no. 7, Art. no. 7, Jan. 2021, doi: 10.3390/rs13071395.

[74] L. Hjorth, “Careful Digital Kinship: Understanding Multispecies Digital Kinship, Choreographies of Care and Older Adults During the Pandemic in Australia,” Commun. Cult. Crit., vol. 15, no. 2, pp. 227–243, Jun. 2022, doi: 10.1093/ccc/tcac008.

[75] A. Yue, “The role of arts and culture in resilient cities: creativity and placemaking,” Handb. Geogr. Creat., pp. 111–127, Sep. 2020.

[76] G. C. C. Douglas, “Individualizing Civic Responsibility: DIY Urban Design in the Help-Yourself City,” in The Help-Yourself City: Legitimacy and Inequality in DIY Urbanism, G. C. C. Douglas, Ed. Oxford University Press, 2018, p. 0. doi: 10.1093/oso/9780190691332.003.0003.

[77] R. Salzman and M. Yerace, “Toward understanding creative placemaking in a socio-political context,” City Cult. Soc., vol. 13, pp. 57–63, Jun. 2018, doi: 10.1016/j.ccs.2017.10.004.

[78] R. Stillwagon and A. Ghaziani, “Queer Pop-Ups: A Cultural Innovation in Urban Life,” City Community, vol. 18, no. 3, pp. 874– 895, 2019, doi: 10.1111/cico.12434.

5 Citizen science, smart art & place making: **conference paper**

Validity of Citizen Science: A qualitative and arts-based evaluation from the perspectives of citizens, academics, artists and ICT-specialists

Tamar Shahinian[1], Leonie van Buuren[2], Marja Peltenburg[3], Marlene Hoynk[3], Dannie van Bemmel[3], Somaya Ben Allouch[4,5], Masi Mohammadi[2], Saskia Robben[4], Marwan El Morabet[4], Barbara Groot-Sluijsmans[1,6*]

[1] Leyden Academy on Vitality and Ageing, The Netherlands

[2] Eindhoven University of Technology, The Netherlands

[3] Stadsdorp Vondel-Helmers, The Netherlands

[4] Amsterdam University of Applied Sciences, The Netherlands

[5] University of Amsterdam, The Netherlands

[6] VU Amsterdam, Amsterdam Public Health Institute, The Netherlands

*Corresponding author: Barbara Groot (b.c.groot-sluijsmans@vu.nl)

Abstract: Increasingly, academics and non-academics collaborate in citizen science projects. However, less attention is paid to the experiences of the validity of citizen science projects for all involved. This study gained insight into the validity experience based on the perspectives of all actively involved people in a Dutch citizen science study focusing on social innovation in public spaces. An evaluation design was used as a methodology, which contained a variety of qualitative and arts-based methods, including sessions, observations, and an open questionnaire. Six validity types of the International Collaboration of Participatory Health Research (ICPHR) were used, namely participatory, intersubjective, contextual, catalytic, empathic, and ethical validity. The results showed that stakeholders' validity-related experiences were 1) diversity in methodological approaches and timelines, 2) academic funding procedure and practice, 3) experiences of responsibility and ownership, and 4) increased empathy of all those actively involved. Experiences of validity of processes in citizen science could differ from the experiences of the outputs and outcomes of a project. Finally, this evaluation shows how qualitative and arts-based methods through the lens of validity could help exchange perspectives on the process of citizen science and (in)directly contribute to increasing empathy for each other's perspectives and approaches.

Keywords: validity; citizen science; quality; participatory research; public engagement

1. Introduction

Worldwide, high ambitions to strengthen the collaboration between academia and society and partnerships outside the university are in place. Collaboration with citizens in social innovation through the design of public spaces can improve outcomes and impact and help build trust and understanding between science and society, enhance empowerment of citizens and ultimately increase the quality of life of citizens living in precarious situations (European Commission, 2021; National Programme Open Science, 2022). Citizen science (CS) is an umbrella term for participatory research approaches and social innovation, referring to the participation of non-academics in scientific studies and other activities with scientific objectives (Eitzel et al., 2017; Haklay, 2013).

Although CS is increasing in popularity worldwide, attention to the evaluation of quality (Broekema et al., 2023), specifically the concept of validity, is still limited. Concepts such as ‘internal validity’ and ‘external validity’ are common in quantitative research. In the last decades, scholars redefined their use of the concept of validity for qualitative research (Golafshani, 2003), for example, to credibility and transferability, including techniques that can be used to meet them (Frambach, 2013). However, these definitions and techniques do not fit citizen science and more general participatory research approaches, because they do not anticipate on its participatory, inclusive and emancipatory nature. From several related fields, action research (Bradbury et al., 2019), technology innovation (Lindhult, 2019) and participatory health research (International Collaboration for Participatory Health Research (ICPHR), 2013), quality dimensions are redefined to encourage debate and reflections on validity issues related to all participants. Surprisingly, to the best of our knowledge, validity as a core concept of qualitative research rigour has not yet been discussed in the field of citizen science itself, except for the focus on the validity of data (Brown et al., 2018).

The ICPHR approach to validity (Wright et al., 2018) fits most with our ‘citizen science’ approach, which is focused on the empowerment of citizens by taking into account the local needs, practices and cultures in their design and implementation (Skarlatidou & Haklay, 2021). This approach to the validity of participatory research practice uses six validity types: participatory; intersubjective; contextual; catalytic; ethical; and empathic (see Table 1). Only two groups of academics have already used these criteria to evaluate the validity of their participatory studies. One of these used a ‘reflexive account’ to share insights on validity (Sitter et al., 2020). The other conducted a framework analysis for data gathered in a participatory evaluation study using various qualitative data-gathering methods (Seale et al., 2021). This paper aims to gain insight into the validity based on the experience and perspective of all actively involved people in a Dutch citizen science study focusing on social innovation in public spaces.

Table 1. Validity Types of Participatory Health Research (ICPHR, 2013)

Validity Types	Focus: Extent to which…
Participatory Validity	… stakeholders take an active part in research process
Intersubjective Validity	… the research is viewed as being credible and meaningful by the stakeholders from a variety of perspectives
Contextual Validity	… the research relates to the local situation
Catalytic Validity	… the research is useful in presenting new possibilities for social action
Ethical Validity	… the research focuses on whether outcomes are sound and just
Empathic Validity	… the research has increased empathy among both the participants and researchers, and both recognize the emotions and perspectives of others without judgements

2. Methods

2.1 Background and Context

The context of this study is a two-year citizen science project that took place in the Netherlands between April 2022 and 2024. The study aimed to encourage social interaction between community members, by co-creating — together with community members (with and without dementia) — an art object located in a public space with integrated artificial intelligence (AI). The two-year study had two hypotheses: 1) AI art objects in public spaces can stimulate social interaction among community members (with and without dementia); and 2) citizens are involved in the research and design of their living environment in a valid and meaningful way by applying citizen science. This paper reports on the second hypothesis.

The team who conducted the full study was transdisciplinary: community members, academics and AI-specialists from different universities, people from an AI small enterprise, community organizations and artists. The first and last author are educated from an emancipatory paradigm with participatory methodology (Abma et al., 2019). The final author is an active scientific member of the ICPHR and has a PhD in participatory health methodology. Community members had different roles, moments and ways of engagement in this study (see Table 2). Two, and later three, leading citizen scientists were the linking pin with a larger group of community members (third to fifth authors).

Table 2. Citizens Who Were Engaged in the Citizen Science Project

Type of citizens	Involvement	Background
Active citizen scientists	Weekly basis	Two older adults (female >65 years)
Semi-active citizen scientists (working group Public Space)	Monthly basis	Six older adults (all women, one of colour >65 years)

Large group of citizens (the City-Village)	Informed by e-mail, website and newsletter and twice a year on an event	70 older adults (mixed gender, most >65 years)
Citizens in the community centre (Greet & Meet)	Group sessions (4 times during the project)	12 older adults (mixed gender and backgrounds >65 years)
Citizens with different phases of dementia (Informal care & Dementia)	Group sessions (3 times during the project in small groups, 2 times in large groups on an event)	15 older adults (mixed gender and background) >65 years

2.2 Methods of Data Gathering and Analysis

We conducted a study with a qualitative evaluation design to gain insight into the validity experiences of actively involved people in this study. We used multiple data-gathering methods and data sources with different participants at various moments (see Table 3) to increase the credibility of the findings (Frambach, 2013). First, the last author conducted a framework analysis using the six validity dimensions (Table 1). Second, a reflexive thematic analysis (Braun & Clarke, 2019) was used together with the first author. Simultaneously, the second author and the last author wrote a Dutch article about the same topic (Groot & van Buuren, 2023). In addition, and simultaneously, we wrote a Dutch product about this topic together with the third, fourth and fifth authors. The other authors reacted to the findings as a member check and deepened the themes. This paper reports mainly on the analysis of the open-ended questionnaire (Table 4) but uses other data sources to illustrate the themes. The ethics committee of the Technical University Eindhoven has approved the study (nr. ERB2024BE10), and participants consented to participate voluntarily.

Table 3. Methods used in this study

Methods	Data sources	Participants	Moment
Validity session	Transcripts of session	Semi-active citizen scientists (working group Public Space)	At the start of the process
Participatory observations	Diary of reflections and observations, written-out quotes based on memory after meeting	The first and last authors	Throughout the process
Reflection moments with the core team	Transcript of audio and reports of dialogue	Full active team excluding artists	Throughout the process
Individual arts-based reflections	Collage, videos and photos of dance reflections, live dance performance, poems	Authors	On meaningful moments

Arts-based group reflections	Photos and transcripts of the tableaux vivant	Semi-active citizen scientists and academic researchers (n=10)	September and November 2023
Open questionnaire	Open answers	Members of the active team (n=6)	Dec 2023
Interview	Transcript of audio	Engaged artists who were also citizens (n=3)	Feb 2024

Table 4. Questions about Validity Types in an Open Online Questionnaire (translated from Dutch)

Validity types	Question (with an addition to every question: write preferably at least two paragraphs)
Participatory Validity	1.How did you experience the participation of all involved at all stages of the study? 2.How actively did citizens participate? And how did you experience that?
Intersubjective Validity	3. To what extent was this project meaningful for stakeholders? And for you? 4.To what extent do you feel the research was credible for the people it involved (people with dementia/citizens)?
Contextual Validity	5. To what extent was the research responsive towards the local context? Research: consider both approach and topic Local context: neighbourhood, residents, use of language, etc.
Catalytic Validity	6. To what extent did you/we respond 'well' to what was needed in that environment? Give specific examples. 7. To what extent was our research project appropriate in this environment? (our topic, but also approach) 8. To what extent did the research contribute to social innovation? (What do you understand by social innovation?)
Ethical Validity	9. What effect did the research have on you? And on citizens? And was that the 'good' thing? 10. To what extent did our research contribute to justice? In particular, name examples where perhaps it did or did not?
Empathic Validity	11. To what extent did the study contribute to increasing empathy between all involved?

3. Results and analysis

Striving for validity in a citizen science study that focuses on social innovation in public spaces is presented in four themes. Validity relates to: 1) the diversity in methodological approaches and timelines; 2) the academic funding procedure and practice; 3) the experiences of responsibility and ownership; and 4) the increased empathy of all actively involved.

3.1 Diversity in Approaches and Timelines Affected Validity Differently

In this study, we worked with stakeholders from different disciplinary backgrounds (built environment, artificial intelligence, health and social care, artists, participatory methodology) and other knowledge bases (experiential knowledge of citizens, academic knowledge, professional knowledge and artistic knowledge), meaning different working approaches and different use of language (jargon). Some were mainly focused on developing and creating social digital innovation and art. Others first concentrated on the process of (participatory) research to understand local needs and find local support before developing an art object for public space. These differences were enriching, helping us become familiar with different ways of working and getting to know each other and, at the same time, leading to friction due to differences in focus, perspectives, priorities, use of specific language and pace of work. Eventually, the development process had to happen at a (too) fast pace, with less time and attention for essential design questions, such as the object's safety, electricity source, maintenance and sustainability issues. For some, the pace and focus of the process affected the experiences of the validity of the (creative) process for the outdoor object. Others were mainly focused on finding support for the development plans from other citizens through preliminary research. The backing of citizens other than those actively involved was meaningful and important. Therefore, in this study, the intersubjective validity (meaningfulness and credibility of the process) was lowered due to the focus on the participatory validity (more people engaged and more in-depth insights into their needs).

It was a long process. And it took [1.5 years] before we could start. My energy was seeping away. But then, suddenly, we had to develop the artwork. We had six weeks, and it had to be ready. That's when all democracy went overboard. Artist

We made a collage about our feeling that things were going too fast [Figure 1]. The process was going too fast. It is a high-speed train, not a slow-paced easy-going local one. (...) The process [of investigating the community's needs] is time-consuming and uncertain. We wanted to take into account the wishes and needs of all kinds of citizens as a basis, but this is not a coherent group [so it takes time!]. Active Citizen Scientist

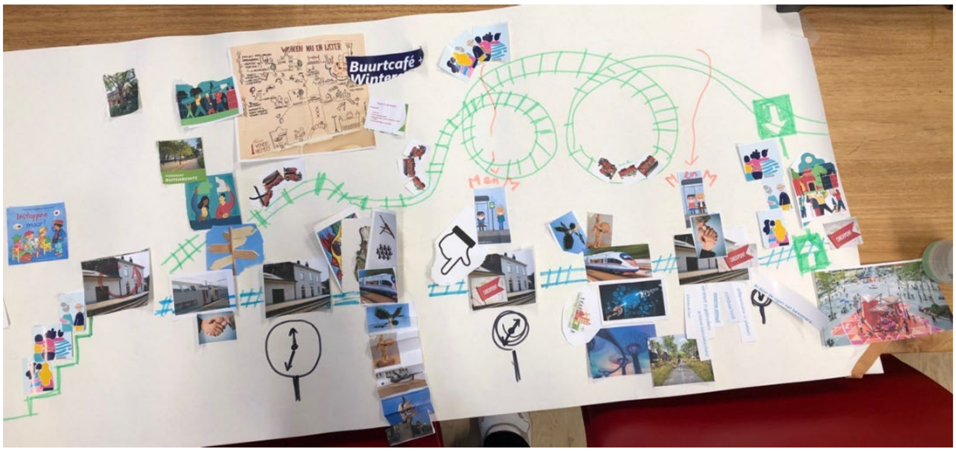


Figure 1.

Collage from one of the Active Citizen Scientists about the Experience in Speed: A High-speed Train vs a Local Train

3.2 Academic Funding Procedure and Practice Impacted Validity

The National Academic Research Fund for Healthcare Research and a government agency promoting innovation in Dutch Life Sciences & Health funded the project. These funds requested a detailed academic proposal with requirements regarding commercial (AI) partners and influenced a focus on including people with dementia. This funding procedure was initiated by the funding body and academia, and stimulated a conversation and movement within the local community. Two active citizens became a permanent members of the academic research team.

This evaluation showed that most academic partners experienced participatory and contextual validity more than citizens and artists. For most academics, the participatory process was as expected and sometimes even exceeded their expectations. In addition, academics pointed out that we focused on relevant societal issues that resonated with the active citizens, so this led to a high contextual validity.

The project suited the local context. It is a creative neighbourhood where citizens enjoy living and are proud of their neighbourhood. Academic AI-specialist

However, the active citizens, AI partners and artists (who lived in the neighbourhood) had a different perspective on these two validity types. Although they perceived their work within the project as meaningful and learned a lot, their hopes and expectations that this project would foster social inclusion and civic engagement during the project process have yet to materialize. Citizens and artists perceived that the academic and AI focus and abstract language hindered the engagement of more citizens in the neighbourhood. Many citizens had a resistance to AI and technology and could not imagine the benefits (yet). In addition, an energy-transition project, with direct and more severe impact on the lives of the community members, asked for more attention in the neighbourhood As an example of artistic and embodied experiential knowledge, one of the academic researchers, who was also a community member, danced her reflections on the challenges during the period. See Figure 2 as an example of this which shows embodied experiences, which focus on the ups and downs in the process.

The participation of fellow community members never got off to a good start, as far as I am concerned. For them, it has always remained too abstract. Therefore, we struggled to activate people to get involved. Active Citizen Scientist

Figure 2. One of the Academic Researchers Who Was Also a Citizen in the Neighborhood Danced Her Reflections on Participation During the Project (https://vimeo.com/930343057?share=copy)

3.3 Experiences of Responsibility and Ownership

In the evaluation, all people involved in this project who lived in the neighbourhood (as well as active citizen scientists and artists as academic scholars) shared concerns about their feeling of a massive sense of responsibility. They were the 'face of the project' in the neighbourhood. Fellow community members were asking them about the project. This sometimes made active citizen scientists unsure. The outcome of the process was that they were unsure with regard to the full project, because it was a transdisciplinary effort in the unknown. This hindered clear communication about a concrete final product to other neighbours.

For me, the project has always been a concern. I felt a commitment but thought I never really lived up to it. At times, I did enjoy it; it was fun (...). Active Citizen Scientist

The main concern arose regarding ownership of the object in the public space. Questions of team members who lived in the neighbourhood were: who is responsible if something happens or people complain? Who will maintain the object? When the research grant ends, who (academics, AI specialists) will stay engaged and share the responsibility and ownership? The photograph (Figure 3) shows the emotions of different stakeholders in the process around this topic. You see a citizen with questions in the middle (woman with purple jacket), people around her who are the other team members, and an academic pointing the way to the future. The person in the middle feels alone and hopes to have support in the long run. The uncertainty about shared responsibilities during and after the end of the project lowered the ethical validity.

I worry about the material. I am willing to maintain the object, but it is not mine. Artists

This study also showed that ownership of an object in the public space can make people proud. If the artistic object becomes a success, it could help the people involved realize their goal of increasing social cohesion, as aspired to with this project. This affected the intersubjective validity in a positive way: it was meaningful for the people involved and the neighbourhood.

This is the most engaging day of my life in this neighbourhood. This is great! [on the day the object was built] Active Citizen Scientist

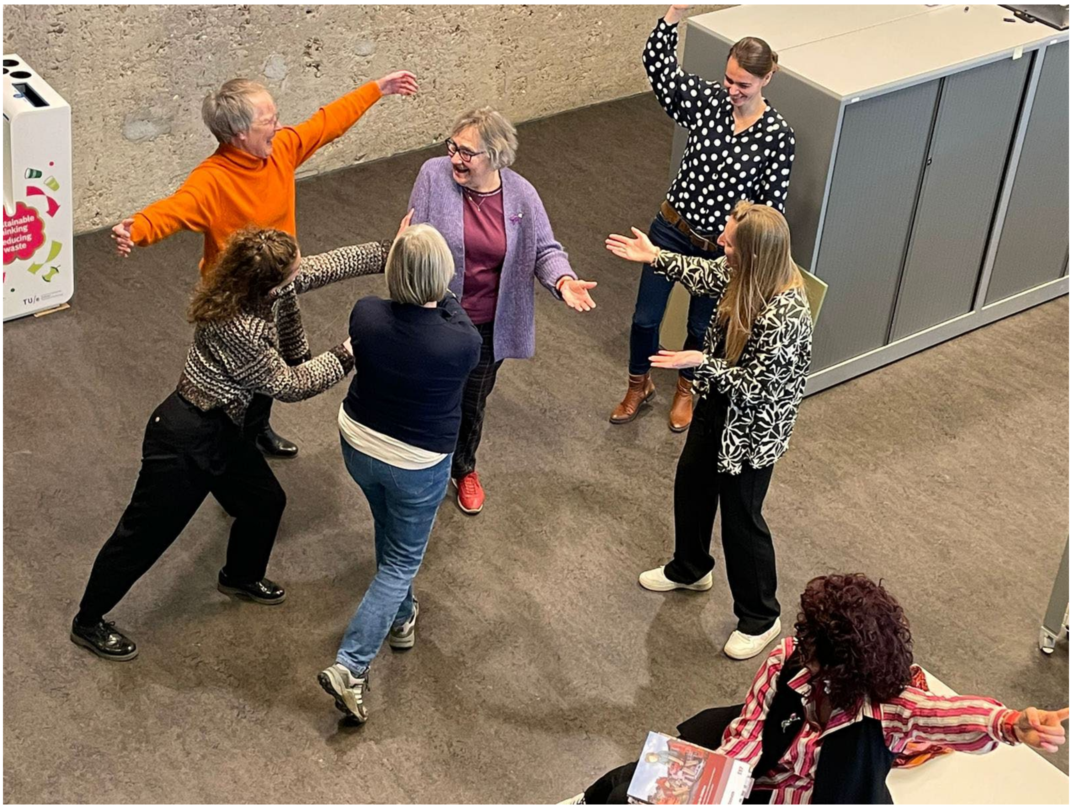


Figure 3. Research Team with Citizen Scientists and Academics Reflecting the Process in a Tableaux Vivant

3.4 Increased Empathy

Finally, this project brought a lot of empathy between the different people involved, especially between the actively involved citizens and researchers. We spent much time understanding each other's methods, language, pace, and communication. By figuring out a way of working together, empathy came naturally. Friction and frustration along the way helped and was dealt with in an open manner. In this process, all those involved showed themselves, were transparent and wanted to learn. There also seemed to be room for discomfort and fun. A good breeding ground was laid after two years. We needed time to understand each other's aims, language, vision and way of working.

Those involved show that not only did they personally learn a lot about transdisciplinary work and cooperation with citizens and academics, but they also learned a lot about how urban citizens (with dementia) think and act. The empathic validity was therefore very high for all.

An empathic connection emerged through trial and error, easy and uncomfortable moments. This also took time. It is a pity that precisely this good breeding ground will be abandoned at the end of March. Active Citizen Scientist

With me: it felt very strange at times to not [only] be in charge, because citizens were also in charge. I am so used to taking directions as a researcher or project coordinator, but this was different. But the difference is very positive here! Nice to see that citizens and researchers stood side by side. Researcher

4. Discussion

This paper showed a methodology to study validity at a process level using different qualitative and arts-based methods. See the findings in relation to the validity types in Table 5. Especially, the dimension of 'Empathic Validity' stood out in this study; the process of citizen science has increased empathy among all stakeholders involved. It showed that the validity of the process of a citizen science project could differ, mainly due to different backgrounds, working approaches, trust, and feelings of responsibility and ownership. In addition, we learned that a valid or invalid citizen science process is not necessarily the same as the validity of a study's result or outcome (like in this process, the creative outdoor object). It made clear the urgency to pay attention to monitoring separately the validity of the process and the validity of the outcome of the process. Finally, this study revealed the high impact of funding procedures and practices on validity.

Table 5: Validity types related to different findings of the study

Validity Types related to different findings	Diversity in approaches and timelines affected validity differently	Academic funding procedure and practice impacted validity	Experiences of responsibility and ownership	Increased empathy
Participatory Validity	High for all	High for academic, and low for community and AI partners and artists	x	x
Intersubjective Validity	Low for all	x	x	x

Contextual Validity	x	High for academic, and low for community partners	Only at the end of the study higher for community partners	x
Catalytic Validity	x	x	x	x
Ethical Validity	x	x	Low for some of the community partners	x
Empathic Validity	x	x	x	High for all

Ownership and responsibility are not new as practical and ethical issues in participatory and citizen science projects (Chesser et al., 2020; Fiske et al., 2019; Groot & Abma, 2022; Guerrini & McGuire, 2022; Rasmussen, 2021). However, only using validity types as evaluation criteria of validity could not oversee all these topics. First, the 4Rs framework (Guerrini & McGuire, 2022) for assessing ownership practices in citizen science is an interesting additional framework, which could ask for more attention to ownership from the start of the project in which people make a creative object. This 4Rs framework focuses on 1) reciprocal treatment, 2) relative treatment, 3) risk-benefit assessment, and 4) reasonable expectations. Including these criteria in participatory evaluation could help avoid underestimating the relevance of ownership. Feelings around ownership and responsibility could also grow or shift during the process. Second, responsibility is the other essential topic for validity in citizen science processes. The Ethics Framework of Citizen Science (Groot & Abma, 2022) could also help to be aware of the ethics work (Banks, 2013) necessary in the citizen science process. Ethics work is often invisible work that is essential to tackle everyday ethical dilemmas about responsibility: it is the effort people put into seeing ethically salient aspects of situations and working out the right course of action. A work package in every citizen science study in which team members pay attention to validity, ownership and ethics work is a pathway for valid citizen science.

5. Conclusion

Experiences of the validity of processes in citizen science could differ in experiences of the outputs and outcomes of citizen science processes. This evaluation shows how qualitative and arts-based methods could help to exchange perspectives on the process of citizen science.

Acknowledgements

We would like to thank all citizens, colleagues and partners in this study for their collaboration. We also thank the funders for their openness to experiment in this project.

References

Abma, T., Banks, S., Cook, T., Dias, S., Madsen, W., Springett, J., & Wright, M. T. (2019). *Participatory*

research for health and social well-being. Springer International Publishing.

Banks, S. (2013). Negotiating personal engagement and professional accountability: Professional wisdom and ethics work. *European Journal of Social Work, 16*(5), 587–604.

Bradbury, H., Glenzer, K., Ku, B., Kjellström, S., Aragón, A. O., Warwick, R., Traeger, J., Apgar, M.,

Friedman, V., Chuan Hsia, H., Lifvergren, S., & Gray, P. (2019). What is good action research: Quality choice points with a refreshed urgency. *Action Research, 17*(1), 14-18.

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative research in sport, exercise and health, 11*(4), 589-597.

Broekema, P., Bulder, E. A., & Horlings, L. G. (2023). Evaluating co-creation in social innovation

projects: Towards a process orientated framework for EU projects and beyond. *Research Evaluation, rvad017*.

Brown, G., McAlpine, C., Rhodes, J., Lunney, D., Goldingay, R., Fielding, K., Hetherington, S., Hopkins, M., Manning, C., Wood, M., Brace, A., & Vass, L. (2018). Assessing the validity of crowdsourced wildlife observations for conservation using public participatory mapping methods. *Biological Conservation*, 227, 141–151.

Chesser, S., Porter, M. M., & Tuckett, A.G. (2020). Cultivating citizen science for all: Ethical

considerations for research projects involving diverse and marginalized populations. *International Journal of Social Research Methodology, 23*(5), 497–508. DOI: https://doi.org/10.1080/13645579.2019.1704355

Eitzel, M. V., Cappadonna, J. L., Santos-Long, C., Duerr, R. E., Virapongse A., & West S. E. (2017). Citizen science terminology matters: Exploring key terms. *Citizen science: Theory and practice*; 1-20.

European Commission (EU) (2021). *European Research Area Policy Agenda – Overview of actions for the period 2022–2024*. Retrieved January 16, 2023, from research-and

innovation.ec.europa.eu/system/files/2021-11/ec_rtd_era-policy-agenda-2021.pdf

Fiske, A., Del Savio, L., Prainsack, B., & Buyx, A. (2019). Conceptual and ethical considerations for

citizen science in biomedicine. In N. B. Heyen, S. Dickel & A. Bruninghaus, (Eds.), *Personal health science* (pp. 195–217). Springer. DOI: https:// doi.org/10.1007/978-3-658-16428-7_10

Frambach, J. M., van der Vleuten, C. P., & Durning, S. J. (2013). AM last page: Quality criteria in

qualitative and quantitative research. *Academic Medicine, 88*(4), 552.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. The Qualitative Report, 8(4), 597–607.

Groot, B., & Abma, T. (2022). Ethics framework for citizen science and public and patient participation in research. *BMC Medical Ethics, 23*, 23. DOI: https://doi.org/10.1186/s12910-022-00761-4

Groot, B., & van Buuren, L. P. G. (2023). Zoeken naar betekenisvol innoveren met burgers. *ICT &*

Health, 2/2023, 36–37.

Guerrini, C. J., & McGuire, A. L. (2022). An ethics framework for evaluating ownership practices in biomedical citizen science. *Citizen Science: Theory and Practice, 7*(1): 48.

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. In: Sui, D., Elwood, S., Goodchild, M. (eds) *Crowdsourcing Geographic Knowledge* (pp 105-122). Springer.

International Collaboration for Participatory Health Research (2013). *What is participatory health research? Position Paper 1*. Retrieved July 4, 2014 from https://tinyurl.com/4e6bs7mj.

Lindhult, E. (2019). Scientific excellence in participatory and action research: Part I. Rethinking research quality. *Technology Innovation Management Review, 9*(5).

National Programme Open Science (2022). O*pen Science 2030 in the Netherlands NPOS2030 Ambition Document*. Version 0.91 | 21 April 2022 Retrieved January 16, 2023, from doi.org/10.5281/zenodo.7010402

Rasmussen, L. M. (2021). Research ethics in citizen science. In A. S. Iltis & D. MacKay (Eds.), *The Oxford handbook of research ethics*. Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780190947750.013.36

Seale, J., Garcia Carrizosa, H., Rix, J., Sheehy, K., & Hayhoe, S. (2021). A participatory approach to the evaluation of participatory museum research projects. *International Journal of Research & Method in Education, 44*(1), 20–40.

Sitter, K. C., Beausoleil, N., & McGowan, E. (2020). Digital storytelling and validity criteria. International *Journal of Qualitative Methods, 19*, 1609406920910656.

Skarlatidou, A., & Haklay, M. (2020). Geographic citizen science design: No one left behind. UCL Press.

Wright M. T., Springett, J., & Kongats, K. (2018). What is participatory health research? In M. T. Wright & K. Kongats (Eds.), *Participatory health research: Voices from around the world* (pp. 3–15). Springer.

5 Citizen science, smart art & place making: **conference paper**

Co-creation as an incentive for enhancement of public familiarity: Interactive artwork in the neighbourhood to connect

Sophie Peters[1*], Masi Mohammadi[1, 2], Gerald Gosselink-Ramos[1]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[2] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

*Corresponding author: Sophie Peters (sophie.peters@han.nl)

Abstract: The consequences of the changing society emphasize the importance of an informal (care) network within the neighbourhood. However, amplifying or establishing local social networks is not straightforward. Instead of focussing on deep-rooted networks, public familiarity as social foundation, established through repeated social interactions, could be highlighted. The project Art of Connection investigates both the process of co-creating interactive art and the artwork itself as a catalyst for accessible encounters, using the neighbourhood Stadseiland in Arnhem as living lab. This article explores the process of co-creation as 1. a method for creating an interactive artwork that people feel a shared responsibility for; 2. as an incentive to experience interactions with unknown neighbours for establishing public familiarity; 3. as a means to amplify existing connections with neighbours. The various research activities proved themselves to be interesting starting points for different interactions, specifically the neighbourhood fair. The fair as contribution to connection could be examined more extensively by exploring its effect on creating new or strengthening existing ties between neighbours in future research. Furthermore, the group sessions contributed to strengthening existing connections, especially when focussing on topics related to encounters and the neighbourhood.

Keywords: public familiarity; co-creation; place making; neighbourhood; Empathic Design Framework

1. Introduction

In order to maintain a well-functioning healthcare system in the Netherlands, while dealing with social changes such as accelerated aging and the increasing pressure on healthcare, policy reforms in recent years have been focussing on innovations such as extramuralisation (Blank, Van Heezik & Niaounakis, 2016). This transition towards extramuralisation, shifting the focus and responsibility more towards the individual and the community with demand-driven care, emphasized the importance of an informal care network within the neighbourhood, especially for vulnerable seniors with reduced mobility (Buffel et al., 2011; Plemper & Van Vliet, 2003; Blank, Van Heezik & Niaounakis, 2016). However, there is a large leap between concepts as 'caring communities' and intensive caretaking. Expecting laymen to perform highly skilled care tasks next to or instead of professional caregivers is detrimental and provides a distorted image. However, over-reliance on informal networks is a glaring risk, with a possibility of being exploitative specifically towards women, who are traditionally assigned caregiver tasks (Haubner, 2020). Therefore, it is important to determine what is feasible within the community, such as aiming for a non-invasive social foundation as part of a preventative strategy. However, amplifying or establishing local social networks is not straightforward. To lower the threshold, instead of focussing on deep-rooted networks, public familiarity as a social foundation could be highlighted.

1.1 Public familiarity

We interpret the concept of public familiarity as recognizing strangers in the neighbourhood to the point where they become familiar as neighbours, which can be established through repeated 'light' social interactions (Blokland, 2009; Fischer 1982; Van Eijk & Engbersen, 2011). This can contribute to establishing mutual trust, a sense of safety, a sense of belonging and a sense of home and community in the neighbourhood (Buffel et al, 2011; Blokland, 2009; Blokland & Nast, 2014). The notion of public familiarity is explored several times through the lens of interconnecting people from different social backgrounds, as it helps recognition through the visibility of co-existing in shared public spaces (Blokland & Nast, 2014; Piekut & Valentine, 2017; Van Eijk & Engbersen, 2011). Ones connection to the 'other', a so-called social tie, is central for public familiarity. Granovetter (1973) distinguishes different social ties as either strong (relating to friends), weak (relating to acquaintances) or absent. In this formulation 'absent ties' refer both to the absence of a bond, as well as the presence of a bond with little profound meaning. To emphasize the difference, Felder (2020) introduces the term 'invisible ties' for the latter as ties to familiar strangers that you may not be aware of, but which are fundamental for your experience of public familiarity.

Aside from relations to familiar strangers, familiarization could be understood in terms of environmental familiarization. This could be explained as becoming so used to the experience of your environment, encompassing all senses, that the surroundings fade to the mere background as habitual furniture (Felder, 2021; Cogger, 2016; Henshaw, 2014). The process of familiarization can lead to stagnation of superficial, yet comfortable knowledge towards the familiar stranger and the familiar environment: there is no need to pay extra attention or learn more about each other if everything is as expected (Blokland & Nast, 2014; Felder, 2021). Disrupting the familiar (and this stagnation) is therefore not necessarily a bad practice, as long the disruption is non-threatening: it could lead to checking in on the neighbour after noticing that they are not doing their routine walk or to a new-found appreciation for the environment (Felder, 2020; Felder, 2021). This gentle disruption could be achieved through initiating a conversation instead of the usual understanding with a familiar neighbour (Felder, 2020). Interactive art can be an interesting and engaging medium for facilitating low-key interactions for familiarization, while simultaneously supporting different types of interactions away from routines as gentle disruption.

1.2 Interactive art & public familiarity

Using interactive art in the public space as a catalyst for accessible encounters or the enhancement of public familiarity is not new. Interactive art can aim to bring people together in multifaceted ways, for example through multi-sensory interaction responding to touch such as 'Marbles' (Studio Roosegaarde, 2011), encouraging teamwork to create interaction with the artwork similar to 'Urban Lights Contacts' (Scenocosme, 2015) or guiding people towards each other using lights such as 'Let's Get Physical' (Northern Lights, 2019), while simultaneously opening up the possibility to monitor its effect on interaction.

In addition to connecting people through interactive art itself, using the process of designing public art in co-creation as facilitator for social interaction is a well-known topic (Matarasso, 1997; Lowe, 2000; Kay, 2000; Carpenter & Horvath, 2022). By involving local residents in the (design) process, they get the opportunity to adopt the artwork and feel shared ownership. Therefore, the responsibility can be transferred to the neighbourhood after completing the research, in order to remain a lasting connecting factor (Lowe, 2000; Semenza, 2003; PSAA, 2019).

1.3 The Art of Connection

This brief overview shows a clear discrepancy between the 'state of science' and 'state of the practice'. Various completed (inter)national projects are described, however research into effects is lacking and the potential of combining the multifaceted connecting qualities of an interactive artwork with a co-creation process is underexplored. Therefore, the project Art of Connection aims to connect knowledge institutes, artists and residents to investigate both the process of co-creating interactive art and the artwork itself as a catalyst for accessible encounters, using the neighbourhood Stadseiland in Arnhem as living lab. Stadseiland was chosen as a living lab, since the initiative came from an active residents' group itself. Bordering the river Rhine and with the green areas, the neighbourhood has many places with potential for encounters. However, solely focussing on accessible encounters for promoting public familiarity does injustice to the rich existing social structures in the neighbourhood of Stadseiland, which could be built upon. Therefore, this paper explores the co-creation process focussing on three objectives:

- As a method for creating an interactive artwork, through which people could establish a feeling of ownership and responsibility over the artwork.
- As an incentive to experience informal and fleeting interactions with unknown neighbours as a way to establish public familiarity.
- And lastly, as a means to reinforce and amplify existing connections with neighbours.

2. Methods

2.1 Framework

The Empathic Design Framework (Mohammadi, 2017) was used as a basis for the research of the project Art of Connection. The framework comprises of four phases (explore, translate, process, and validate) in order to gain insights to realize and test a human-centred living environment. According to this framework people are not only subject of the research, but they can have an active contribution, in which perceptions, needs and wishes are explored through a co-creation process.

What sets this framework apart is its iterative approach, tailored for the scope of the Stadseiland neighbourhood, encompassing a diverse array of individual perspectives and voices. In the project of Art of Connection, the phases of the Empathic Design Framework are completed in two iterations, as the project impacts the scale of the entire neighbourhood Stadseiland. Initially focussing on smaller, representative groups within the neighbourhood, the approach evolved into a broader inclusion in the second iteration, marked by a neighbourhood-focused event: a small-scale fair in the local park.

This methodological framework aims to foster an interactive artwork that encourages informal interactions between unfamiliar neighbours and strengthens existing neighbourhood connections. By directly involving residents and employing a variety of methods, our research process reflects a deep understanding of the social and cultural dynamics within Stadseiland, essential for achieving the project's objectives.

2.2 Resident involvement

Identifying and engaging specific resident groups active within the neighbourhood was achieved through the connections of an engaged resident and discussions with the neighbourhood coordinator, the so-called liveability coordinator. This engagement led to the participation of three distinct groups: Stadseiland-Noord, consisting of residents active in various community initiatives, Impian Kita, which includes residents united by their shared cultural background, and Eilandstaete with residents grouped by shared care needs. This diversity enriches our project with a wide range of insights and perspectives.

2.3 Methods and activities

Our qualitative approach is designed to delve into residents' needs and wishes deeply. We employed a variety of methods including co-creation sessions and focus groups, facilitated through creative sessions, participatory mapping, collage making, and brainstorming discussions. These methods served multiple objectives: informing about the project's progress, inspiring by highlighting the neighbourhood's significance for its residents, collecting direct feedback on design alternatives for the artwork, and connecting residents with each other and the project. The activities, ranging from focus group sessions with different resident groups to a neighbourhood fair, and meetings organized by residents themselves, were integral to these methods. They were not just aimed at gathering feedback on the art object but also played a crucial role in achieving the project's broader goals.

This integrated approach highlights the coherence and depth of our research methodology, clarifying how each component contributes to the overarching goals of the Art of Connection project. The direct involvement of residents and the use of diverse methods and activities underscore a commitment to understanding the nuances of social and cultural dynamics within Stadseiland, crucial for the project's success.

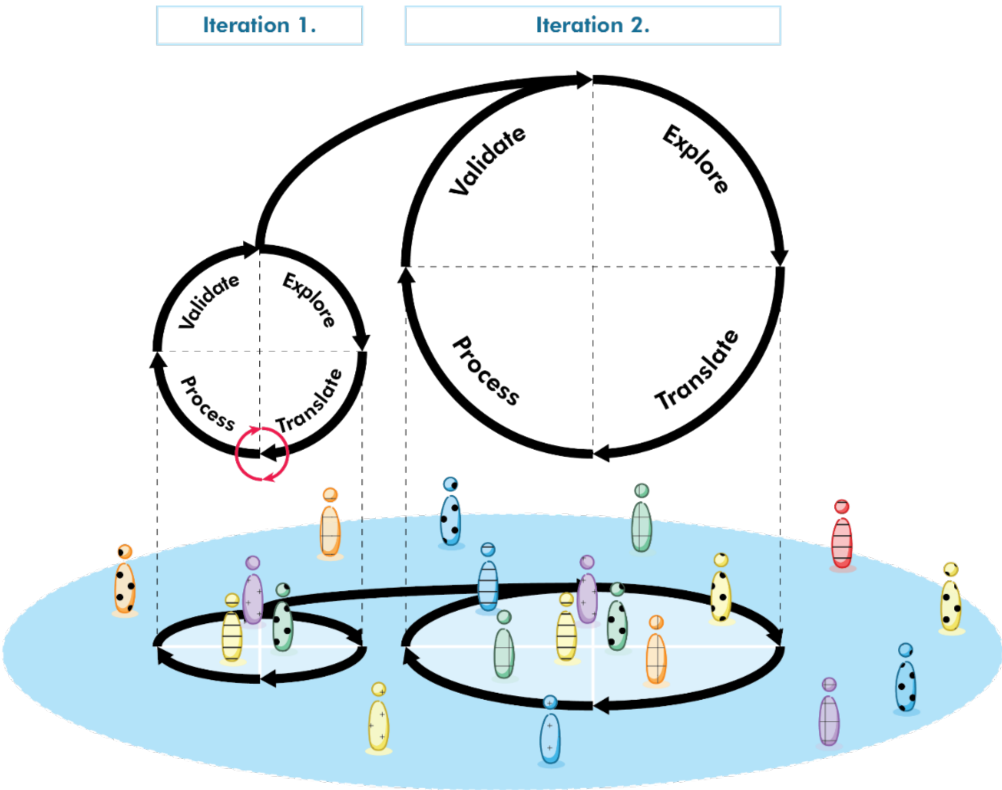


Figure 1. Adaptation of Empathic Design Framework (Mohammadi, 2017), showing the inclusion of resident groups during the process

3. Results and analysis

3.1.1 Iteration 1: Group sessions

The group sessions (n=7) focused on the topics ‘interactive artwork’, ‘encounters’ and ‘the neighbourhood’, addressing the latter two in a combined session. Prior to the group sessions, an introductory meeting with each resident group was held during which the structure and purpose of the project were discussed. The sessions were guided by at least two researchers, with the exception of one session in which a researcher was assisted by a resident who had already experienced a few sessions themselves.

• **Artwork**. During these sessions, participants reflected on different design alternatives presented by either the artists or the researchers using presentation boards with visualizations. The focus of the sessions alternated between individual input using post-its and group discussions. Aside from the post-its and the researchers’ notes, data was collected using sound recordings and in one case a video recording during a hybrid session. This data was analysed and incorporated by the artists into new design alternatives, which were the focal point of subsequent co-reflection sessions. These sessions provided direct feedback for the artwork.

• **Neighbourhood**: These sessions started with a brainstorm regarding encounters, the neighbourhood itself and making new contacts in the neighbourhood. Following the brainstorm, participants made and presented collages of their ideal situation regarding encounters in Stadseiland. Next, participants indicated their perceived boundaries of their neighbourhood individually on a map. During the sessions, the researchers combined participants’ responses into a symbol for the neighbourhood, in order to verify the interpretation of their experience, which were discussed to wrap up. Aside from the physical data, such as the brainstorm paper, the maps and the collages, data was collected through sound recordings. This data was incorporated as indirect feedback in the artwork.

3.1.2 Description of the groups

Stadseiland-Noord. These residents consciously play an active role in the neighbourhood. They live throughout the neighbourhood, especially in the northern part. They are affiliated in various formations with various active clubs or committees, such as the community garden (‘de Burchttuin’), the residents' association and the residents' initiative ‘Stadsburen’. Residents from Stadseiland-Noord feel a strong and proud bond with their neighbourhood. They value the sense of shared identity in Stadseiland, coming from local characteristics and the neighbours, stating: “You just can’t do without the neighbours”, “you cannot move the neighbourhood with you” and “I’m proud of Stadseiland.” The residents repeatedly used ‘encounters’ and ‘activities’ as interchangeable concepts, highlighting their expectation of an active attitude and approach from both parties of the encounter. They view encounters either as organized, planned or semi-spontaneous activities, for example sitting at a public place with a small group (“and a bottle of wine!”) and see who comes along and lingers.

Impian Kita. These residents consciously live together due to their shared cultural and Indo background. They live spread over two apartments facing the central neighbourhood park and have a common room in one of the two apartment complexes. Residents from Impian Kita feel a strong bond with each other. Aside from their local community they appreciate the opportunities to connect with the lively Indo-community across Arnhem, during recurring party nights and activities. Similar to Stadseiland-Noord, these residents interpret 'encounters' as doing something together, such as a game of chess or a BBQ, perceiving this as an attractive idea.

Eilandstaete. These residents live together due to a shared need for care, focussing less than the other two groups on their collective community. Due to the vulnerability of the group, as the participants had different physical and cognitive disabilities, the session was adjusted to the capabilities of the participants. During the session, residents from Eilandstaete commented predominantly on individual basis, sharing personal experiences and stories from their lives before living in the care home. For one resident the potential demand for an active attitude towards encounters seemed quite overwhelming: "There is already so much to do, I don't need more activities". Others stated widely varying needs regarding encounters: "They are all strangers". "But that is so much fun to me!", emphasizing the need to facilitate different settings and possibilities for different kinds of encounters.

Table 1: Participation of different resident groups in co-creation sessions

<table>
<tr><th>Type of residents</th><th>Distinct characteristics</th><th>Overlapping characteristics</th><th>Number of residents</th><th>Focus of the co-creation session</th><th>Applied methods for sessions</th></tr>
<tr><td rowspan="2">Stadseiland-Noord</td><td rowspan="2">-Choice to take an active role in the neighbourhood
-Strong bond and shared identity as 'Stadseilander'</td><td rowspan="5">Mainly 60+, affinity with art, interest in the neighbourhood</td><td>14</td><td>Artwork</td><td>Brainwriting & group discussion</td></tr>
<tr><td>7</td><td>Neighbourhood</td><td>Brainstorm, collage, participatory mapping & group discussion, walking interview</td></tr>
<tr><td rowspan="2">Impian Kita</td><td rowspan="2">-Choice to live together
-Strong bond, related to their common cultural background</td><td>5</td><td>Artwork</td><td>Brainwriting & group discussion</td></tr>
<tr><td>4</td><td>Neighbourhood</td><td>Brainstorm, collage, participatory mapping & group discussion</td></tr>
<tr><td>Eilandstaete</td><td>-Need for care</td><td>5</td><td>Neighbourhood</td><td>Brainstorm, collage & group discussion</td></tr>
</table>

	-More individually oriented rather than a group				

3.1.3 Bridging islands

All three groups emphasized the presence of different social islands within the neighbourhood, with Stadseiland-Noord and Impian Kita expressing the desire to cautiously bridge those different social islands. Both these groups indicate that they are struggling with connecting to other groups. For Impian Kita this means that they would strive to be more approachable for interactions, even though they appreciate being a close-knit group. According to one resident: "Other residents from the neighbourhood used to walk by and ask questions when they saw us on the terrace. Now they know already that we are quite a closed community. It is a pity that they pass by now." Residents from Stadseiland-Noord mention that they find it difficult to connect with residents outside their bubble, and simultaneously like to attract new active people to join their group. They would like to envision the neighbourhood as one big house, with the public space as an extension of a common living room, but admit that this vision does coincide not with the current situation. Residents from Eilandstaete affirm the complication of bridging social islands, but point more to physical accessibility due to limited mobility as an obstacle.

3.2 Iteration 2: The fair

The results distilled from the group sessions were translated by the artists into a Augmented Reality (AR) prototype of the artwork, which was then tested during the neighbourhood fair. Aside from the AR prototype (n=15), the fair consisted of different (research) activities, including participatory mapping for outlining the perceived neighbourhood (n=8), a preference study regarding various interaction techniques (n=10), writing a card for an unknown neighbour (n=4), an exhibition with student projects for inspiration and live music by the neighbourhood band. In addition to the band, residents from different resident groups were also actively involved in the organizational side of the fair, by providing satay for the visitors, assisting during setting up and dismantling the stands and promoting the fair with posters in their windows, highlighting their position as equal stakeholder within the project.

Aside from the posters on the windows, the fair was promoted with flyers delivered door to door, a message on the neighbourhood Facebook, announcements on (websites of) local newspapers and a poster at the local supermarket. The fair attracted about 80 curious residents, considerably expanding the group of participants compared to the first iteration and including resident groups that were not represented before, particularly parents with kids. The fair proved to be a nice setting for accessible encounters connecting neighbours to the project and, more importantly, to each other.

Both the direct and indirect feedback were analyzed again and translated into a physical prototype, specifically changing the artwork into a movable object.


Figure 2 and 3. The fair as setting for accessible encounters connected neighbours to the project and each other

4. Discussion and conclusion

The prototype has not yet been completed, so its effect on providing accessible encounters is still to be explored and validated. In addition, it has not yet been demonstrated whether and how the project will have a future impact on extramuralization. However, the process of working towards the prototype in co-creation with the residents has been finished.

4.1.1 Co-creation as a method for creating an interactive artwork, through which people could establish a feeling of ownership and responsibility over the artwork

Sense of ownership

One of the groups involved has demonstrated a pronounced sense of ownership and responsibility regarding the artwork, as reflected in their enthusiasm and initiative to organize the maintenance of the artwork even before construction, and by inviting us to join their own meetings after the research activities were completed. The other two groups have not shown a sense of ownership this explicitly. Because the artwork is movable and needs shelter during the night, it is possible to temporarily make different groups responsible for providing accommodation, potentially including groups that are not yet involved in the project. This way, we will try to balance between the different groups to prevent appropriation and exclusion in the upcoming phase. However, we should not have too high expectations of assigned responsibility converting into an experienced sense of ownership: although some groups were assigned a specific task in the organization of the fair, their involvement in the fair was not outward translated into a deeper connection to the artwork or the process.

4.1.2 Method for interactive artwork

As the co-creation involved (vulnerable) residents, the research asked for a flexible and accessible approach from all stakeholders. This resulted in a dynamic process in which not only the design for the prototype was adapted, but the process as well, both through input from the residents and external factors such as the change of location and involvement of partners. Because of these constant changes, it was important to guard the original goals of the project and to prevent an endless continuation in the hope of improving the design to everyone's wishes.

Although the project specifically targeted seniors, there is a notable group that was absent from the conversations, namely young people. They have been the subject of discussion multiple times, particularly in relation to fear of nuisance or vandalism and the recognition that there are not many facilities for young people in the area. Even though we organized different research activities aimed at different resident groups, specifically during the fair, we were not able to include the youth within the timeframe of the project. We hope to get their perspective from the tests with the prototype.

4.2 Co-creation as an incentive to experience informal and fleeting interactions with unknown neighbours as a way to establish public familiarity

Residents are very aware of island formation and separation in the neighbourhood, so much so that indicating the boundaries of the neighbourhood could even give a feeling of exclusion towards the other groups: "It feels so unkind." "Yes, you are not allowed to join!". This awareness of the 'other groups' already might suggest the existence of invisible ties. At the same time, the groups indicated both the challenge and aspiration of bridging the islands, emphasizing the importance of a safe setting for fleeting interactions with unknown neighbours.

The fair temporarily established this setting for informal, accessible and easy contact, with neighbours from different groups being in close proximity to each other. A local, convivial and relaxed event like the fair proved itself an interesting starting point for low-key interactions and could be used more extensively for exploring its effect on creating new or strengthening existing ties between neighbours in future research.

In addition to making new connections with neighbours, connections with researchers were also made. Particularly with Eilandstaete, residents used the session to talk about their own past and to share personal stories with the researcher. These connections provide valuable insights for the research, but after the project the researcher disappears from the neighbourhood and with it this connection disappears. This relationship between researcher and participant is something to be aware of in order to also involve other residents in such moments.

4.3 Co-creation as a means to reinforce and amplify existing connections with neighbours

The group sessions were organized with groups that already had an existing connection. Especially the sessions focusing on the neighbourhood and encounters appeared to contribute to solidifying those existing connections, as residents themselves proclaimed: "This session itself is already connecting". During the sessions regarding the artwork this contribution was not explicitly mentioned, possibly as these sessions evoked more individual perspectives and personal preferences.

Aside from organizing our own research activities, we were invited to join activities from the different groups. This gave us the opportunity to benefit from existing structures in the neighbourhood and to embed our research as part of a sequence of fun activities and in-depth discussions. The activities from Art of Connection served as a nice addition, but for truly amplifying and deepening their local connections, it is important that the resident groups continue the work and enthusiasm they already embody.

Future research

This project aimed to create and reinforce a foundation for neighbourhood connections in Stadseiland, acknowledging the importance of having different types of relationship ties for different aspects in life. This foundation showed to be an interesting starting point to further explore, especially focusing on establishing invisible ties between different resident groups. However when moving beyond public familiarity and working towards more rigid aspects of extramuralization, it is important to examine what ties are actually necessary for a type of relationship revolving around receiving and giving (informal) care in the neighbourhood.

Acknowledgements

We would like to thank the residents of Stadseiland for their involvement with Art of Connection. Art of Connection is realized through a subsidy from SIA.

References

Blank, J., van Heezik, A., & Niaounakis, T. (2016). Productiviteit van overheidsbeleid: Deel 2 (De Nederlandse zorg, 1980-2013). Delft: Uitgeverij Eburon.

Blokland, T. (2009). Oog voor elkaar: Veiligheidsbeleving en sociale controle in de grote stad. (Solidariteit en Identiteit). Amsterdam: Amsterdam Univ. Press.

Blokland, T., & Nast, J. (2014). From Public Familiarity to Comfort Zone: The Relevance of Absent Ties for Belonging in Berlin's Mixed Neighbourhoods. International Journal of Urban and Regional Research, 38(4). https://doi.org/10.1111/1468-2427.12126

Buffel, T., Demeere, S., De Donder, L., & Verté, D. (2011). Fysieke, sociale en psychologische dimensies van de woonomgeving: Ouderen aan het woord over hun verbondenheid met de buurt. Tijdschrift voor sociologie, 32(1): 59-87.

Carpenter, J., & Horvath, C. (2022). Co-Creation and the City: Arts-Based Methods and Participatory Approaches in Urban Planning. Urban Planning, 7(3), 311-314. https://doi.org/10.17645/up.v7i3.6106

Cogger, R. (Ed.). (2016). Tuning in and out of place (1 ed.). Routledge. https://doi.org/https://doi.org/10.4324/9781315676456.

Felder, M. (2020). Strong, Weak and Invisible Ties: A Relational Perspective on Urban Coexistence. Sociology, 54(4), 675-692. https://doi.org/10.1177/0038038519895938

Felder, M. (2021). Familiarity as a Practical Sense of Place. Sociological Theory, 39(3), 180-199. https://doi.org/10.1177/07352751211037724

Fischer, C. (1982). To dwell among friends: Personal networks in town and city. Chicago: University of Chicago Press.

Granovetter, M. (1973). The strength of weak ties. American Journal of Sociology 78(6), 1360–1380.

Haubner, T. (2020). The exploitation of caring communities. Global Labour Journal, 11(2), 89-102.

Henshaw, V. (2013). Urban Smellscapes: Understanding and designing city smell environments (1 ed.). Routledge. https://doi.org/https://doi.org/10.4324/9780203072776

Kay, A. (2000). Art and community development: the role the arts have in regenerating communities. Community Development Journal, 35(4), 414-424. https://doi.org/10.1093/cdj/35.4.414

Lowe, S. (2000). Creating Community. Journal of Contemporary Ethnography, 29(3), 357-386.

Matarasso, F. (1997). Use or Ornament? The Social Impact of Participation in the Arts, Comedia, Stroud, UK.

Mohammadi, M. (2017). Empathische woonomgeving. Eindhoven: Technische Universiteit Eindhoven

Northern Lights. (2019). Let's Get Physical [Interactive art]. https://northernlight.nl/project/lets-get-physical/

Piekut, A., & Valentine, G. (2017). Spaces of encounter and attitudes towards difference: A comparative study of two European cities. Soc Sci Res, 62, 175-188. https://doi.org/10.1016/j.ssresearch.2016.08.005

Plemper, E., & Van Vliet, K. (2002). Community care: de uitdaging voor Nederland (RMO Advies 25).

PSAA Portland Street Art Alliance. (2019, October 9). Sunnyside Piazza. Retrieved from: https://www.pdxstreetart.org/articles-all/sunnyside-piazza

Scenocosme. (2015). Urban Lights Contacts [Interactive art]. https://www.scenocosme.com/urban_lights_contacts_e.htm

Semenza, J. (2003). The intersection of urban planning, art, and public health: the Sunnyside Piazza. American Journal of Public Health, 93(9), 1439-1441. https://doi.org/10.2105/ajph.93.9.1439

Studio Roosegaarde. (2011). Marbles [Interactive art]. https://studioroosegaarde.net/project/marbles

Van Eijk, G. & Engbersen, R. (2011). Facilitating 'light' social interactions in public space: A collaborative study in a Dutch urban renewal neighbourhood. Journal of Urban Regeneration and Renewal, 5 (1), 35-50

5 Citizen science, smart art & place making: **conference paper**

The provision and use of communal spaces in high-rise residential buildings for social interaction, findings from in-depth interviews

Linh Nguyen[1, 3]*, Pauline van den Berg[2], Astrid Kemperman[1], Masi Mohammadi[1, 4]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Fontys University of Applied Sciences, The Netherlands

[3] Hanoi Architectural University, Vietnam

[4] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

*Corresponding author: Linh Nguyen (p.m.l.nguyen@tue.nl)

Abstract: This study aims to examine the communal spaces in low-income high-rise residential buildings and their impacts on social interactions. Whether or not high-rise housing is suitable for people's needs depends not only on the apartment unit or building but also on the immediate surroundings of the housing estate. This study, therefore, will investigate social interaction in the communal space within the building (circulation areas and shared facilities) and the immediate surroundings (outdoor spaces). In-depth interviews were undertaken in 2019 to investigate residents' social interactions and space uses for different forms of social interactions, drawing on four different high-rise building complexes in the city of Hanoi, Vietnam. The findings of this study show that residents' social interaction takes place spontaneously in common spaces adjunct to their homes and buildings (e.g. corridors, lift lobbies, and front yards). The lack of shared spaces and the spaces misused in these housing have been seen to create conflicts and annoyance among residents.

Keywords: social interaction; communal spaces; high-rise residential buildings; qualitative interview

1. Introduction

For decades, developers have criticized high-rise buildings as restraining social interaction and being more suitable for office and commercial purposes (Modi, 2014). High-rise residential buildings often consist of isolated and dull boxes with limited surveillance between residents and the outside environment (Al-Jokhadar & Jabi, 2016b; Ridwana et al., 2018). Its high density and spatial limitation are believed to hinder social interactions among residents (Abu-Ghazzeh, 1999; Nguyen et al., 2020; Ridwana et al., 2018). Thompson (2021) states that the number of people living in high-rise residential buildings is increasing, and we need to ensure the design, planning, and management of high-rise residential buildings will meet people's social needs to make these great places to live, now and in the future. It is, therefore, important to understand the living patterns of residents to provide reliable evidence for the design of buildings and living environments that reflect the social needs of residents (Al-Jokhadar & Jabi, 2016a; Wu & Ge, 2020).

Known as a tangible outcome of urbanization and modernization, high-rise housing in Asia in general and Vietnam in particular, is considered to neglect locality (Choi et al., 2014) and lack consideration of housing cultures (Choi et al., 2013). This relatively new type of housing in Vietnam is often developed without modification to meet the requirements of the living patterns and behavior of its residents (Dinh, 2011; Geertman, 2007; Nguyen, 2016). It is therefore essential to consider the design of high-rise residential buildings in association with the socio-cultural context of Vietnam.

Unlike the urban-rich people, who can afford private villas, detached houses, city tube houses, or more expensive high-rise housing situated in more appealing neighborhoods (Costello, 2005; Gifford, 2007), low-income people tend to look for low-cost high-rise residential buildings because they can provide minimal housing needs at affordable prices (Nguyen, 2016). Nonetheless, studies on vertical urban development often focused on middle and high-income customers and real estate entrepreneurs as the drivers of high-rise buildings (Webb & White, 2022) and rarely considered the social needs of low-income groups in high-rise housing. Furthermore, low-income people are believed to have fewer opportunities to access social network resources outside their neighborhoods (Moore et al., 2011) and have more need for social support (Abdul Aziz & Ahmad, 2017; Nguyen et al., 2024). As a result, they have a greater demand for neighborhood-based social interaction. Therefore, it is especially important to recognize and investigate the social needs of low-income groups in high-rise neighborhoods.

Social interactions between neighbors are more than just recognizing one another's faces, it is about communicating with one another, participating in common activities, and lending a hand to one another (Karsten, 2022). Studies have shown that social relationships are impacted by both the "use of space" and "attributes of the physical environment" (Muhuri & Basu, 2021). This study uses in-depth interviews to investigate residents' social needs and their use of spaces for social interaction and objective measurement including collecting project documents, photos, and observation notes to measure the physical environment.

The immediate (near-home) environment has the potential to foster communication and recognition of common interests, therefore, bringing social spaces closer to residents can promote social interaction (Abu-Ghazzeh, 1999; Siew Bee & Poh Im, 2016). Whether or not high-rise housing is suitable for people's social needs depends not only on the apartment unit or building but also on the immediate surroundings of the housing estate (Karsten, 2022). This study, therefore, will focus on the communal spaces within high-rise buildings and the immediate surroundings where residents can regularly see each other and participate in social activities. Qualitative in-depth interviews were undertaken in 2019 to investigate residents' perception of neighborhood social interaction and spaces used for different social interactions in high-rise residential buildings, drawing on case studies in Hanoi.

The following sections will first discuss the Methodology. Next, Section 3 will present the Results and Analysis. The final section is Discussion and conclusion.

2. Methodology

2.1. Context of the study

Four low-cost high-rise residential complexes located in Ha Dong district were selected for this study. This fast-growing district is located in Hanoi's development axis. All buildings in these complexes were occupied after 2010 and have a height greater than 9 floors, which are identified as high-rise buildings according to the High-Rise Building – Geography Survey (2006). Different criteria of the residential areas were also taken into consideration such as accessibility to lakes/parks, availability, and accessibility of indoor and outdoor communal spaces. They also range in size, urban form, and occupation year.

2.2. Methods

Qualitative in-depth interviews were used to investigate residents' experiences with the use of communal spaces for social interactions in high-rise housing. It aims to answer the research question: How is the communal space within high-rise residential buildings and the immediate surroundings related to residents' social interactions? Several sub-questions were used for the in-depth interviews: (1) how do the people use the communal spaces within the building and in the immediate surroundings, and how does that affect their social interactions? (2) how does high-rise living affect people's perceived crowding and privacy and what design elements affect the level of privacy? (3) What are the major factors that hinder interactions between residents in high-rise neighborhoods, and what are the possible interventions to foster stronger social interactions? Drawings, photos, and observation notes were collected as data sources to investigate to support the findings of the in-depth interviews. An evaluation was performed using thematic analysis of the in-depth interviews. The thematic analysis aims to identify the themes and patterns in the data set that are important and related to the overall research questions (Clarke and Braun 2017).

Convenience sampling, a non-probability (non-random) sampling approach, is used to recruit participants. Selected individuals from the target population need to meet criteria such as easy accessibility, proximity to a given location, availability at a specific time, or willingness to engage in the study (Dörnyei, 2007).

Sample size in interview studies is frequently justified by interviewing participants until data saturation is reached. According to Francis et al. (2010) and Guest, Bunce, and Johnson (2006), roughly 12 interviews are required to achieve saturation. This study took place in four different complexes between July and September 2019 in Hanoi, Vietnam. The number of residents that participated in the interviews was 22, 10, 10, and 3 from Kien Hung, Thanh Ha, SDU, and Dai Thanh, respectively. The interviews on average lasted 30-60 minutes.

2.3. Data collection

First, permission was sought, and the contents of the study were explained in detail to each building association. Subsequently, a door-to-door visit was employed to recruit participants for the interviews. Individuals were asked if they were willing to participate in this study. The visits took place at varying times of day, also in the evening, to include working people. Before the in-depth interviews were conducted, residents were informed about the purpose of the study and given assurance about ethical principles, for instance, anonymity and confidentiality. In-depth interviews were held with 45 residents of selected high-rise residential buildings to acquire their experiences with social interactions within the buildings and the immediate surroundings. Each interview lasted for around 30 minutes to 45 minutes. During the interviews, an interactive and flexible approach was adopted. To acquire a more in-depth understanding, questions were adjusted based on the responses of the respondents. Open-ended questions allow respondents to express their real sense of understanding of a situation in their own words. As a result, the interviews resembled guided conversations rather than strictly structured interviews.

An evaluation was performed using thematic analysis of the in-depth interviews. Thematic analysis has been seen as the fundamental method that provides an accessible and theoretically flexible approach to qualitative analysis (Clarke & Braun, 2017). The thematic analysis aims to identify the themes and patterns in the data set that are important and related to the overall research questions. In general, the themes reflect the facts that are summarized from the data set, rather than analyzed (Maguire & Delahunt, 2017). The interviews were done in Vietnamese therefore the transcripts were also coded in Vietnamese, which were then translated into English. Meaning can be lost throughout the translation process, hence the study tries to keep the transcripts and coding in the language of origin as long as possible to prevent constraints in the analysis.

An objective measurement was conducted to measure the communal spaces within and surrounding buildings. Characteristics of the four high-rise residential buildings are presented in Table 1.

Table 1. Characteristics of the four high-rise residential buildings

	Kien Hung	Thanh Ha	SDU	Dai Thanh
		Immediate surroundings (Site planning)		
Location relative to the city center	City fringe	City fringe	Inner city	City fringe
Connection to public streets	 Connected to city streets via internal roads	 Connected to city streets via internal roads	 Directly connected to city street	 Directly connected to city streets (separated by a green fence)
Accessibility to outdoor space	An open green space separates the building from the surrounding area	Three buildings surround one front yard	No open spaces in the immediate surrounding	3 buildings are connected and surrounded by a walkway
		Within the building		
Provided services/parking facilities	1 basement parking garage (motorbikes and bikes). Cars park on the internal road Rooftop terrace: empty, some people used to hanging clothes Shops (convenience shop, pharmacy, hair salon) are on the street level	1 basement parking garage (motorbikes and bikes). Cars park on the internal road Kiosks (retail shops, coffee shops, etc.) are on the street level, all along the frontages	1 basement parking garage (cars, motorbikes, and bikes) A fashion store in front of the building and one convenience shop located within the main hall	1 basement parking garage (motorbikes and bikes). Cars park on the internal road Shops are on street level and all along the frontages, and a parking garage is in the basement
Entrances types	The main and side entrances lead to the lift lobbies on the two sides of the building.	The main and side entrances lead to the lift lobbies on the two sides of the building. The lift lobby on the ground floor is immediately on the side entrance and directly connected to the outdoor courtyard without a buffer zone.	Only one entrance leads to the main hall and 2 lift lobbies	The main and side entrances lead to the lift lobbies on the two sides of the building.
Common spaces	Common room located on the ground floor	3 buildings shared one common room for meeting and private parties	(1) Playroom (2) Study room (3) Sports area (4) Meeting Room and (5) a private kinder garden	1 common room on the second floor
Architectural variation	Long corridor – Z-shaped	Long corridor – I-shaped	Short corridor	Long corridor – H-shaped
	Two modules are joined together to form a housing block.	Double-loaded corridor: apartment units are organized on both sides of the central corridor	Two modules are joined together to form a housing block.	Point-block or tower apartment with 20 flat units organized around the service core

3. Results and analysis

3.1. Characteristics of the four high-rise residential buildings

SDU and Dai Thanh are located in high-density areas and are directly connected to city streets. Whereas, Kien Hung and Thanh Ha are in the expanded development area of the city and connected to city streets via internal roads which have more visual as well as auditory and social privacy. The entrances of buildings in SDU and Thanh Ha are immediately on the pavement grounds. There is no gradual transition from public to private. On the contrary, the entrances of buildings in Kien Hung and Dai Thanh connected to front yards as extensive transitional areas.

Compared to other buildings SDU provides a wider variety of indoor facilities including a children's playroom, meeting rooms for residents, and a study room on 2 separate floors, though they are small. Kien Hung has a flexible common room on the ground floor for people to set up their own spaces for exercise. Thanh Ha and Dai Thanh only provide spaces for formal meetings that are on the same floors as apartment units and are not accessible by residents on a daily basis.

SDU has divided corridors, whereas Kien Hung, Thanh Ha, and Dai Thanh have straight corridors running through the full length of the building. Kien Hung and Dai Thanh have 2 corridors on both sides of the lift lobbies while Thanh Ha has one long corridor. The entire ground floors in Thanh Ha and Dai Thanh are divided into many small spaces for kiosks such as café, convenience shops, beauty salons, and a variety of the necessary goods for the daily use of residents. While Kien Hung and SDU ground floors are only limited to a few simple services like pharmacy and convenience shops.

3.2. Analysis of spaces used for social interaction.

The interviews aim to acquire people's social interactions and their uses of spaces. The main themes drawn from the interview data included the use of communal spaces for social interactions in (1) circulation areas, (2) shared facilities, and (3) outdoor spaces and the design elements that affect perceived privacy and social interaction. The results of the interviews show that crowding, lack of meeting spaces, and/or limited access to public facilities can lead to behaviors that are not suitable for high-rise living and may result in a detrimental impact on people's quality of social life.

3.2.1. The use of communal spaces

3.2.1.1. The use of circulation areas for social interactions

From the interviews, it became clear that many residents tend to use circulation areas (e.g. corridors, lift lobby, and stairs landing) for social activities (Figure 1). However, these spaces are not specifically designed for social activities.

We organize parties in the corridor on different occasions...children's day, women's day, or monthly birthdays of children. (Woman, 18-34, Kien Hung) I miss the vibes in my detached house where I can always see and reach out to neighbors. Thus, sometimes we, a few women place mats and sit in the corridor talking while watching our children playing. (Woman, 55 or older, Kien Hung)

Figure 1. Full moon festival party for children living in the main hall of the building (2021)

Some people who live next to the staircase in SDU said that besides neighbors living on the same floor, they also keep contact with neighbors on other floors.

> My apartment is on the side of the elevator lobby and connected to the staircase lobby by a short hallway. Sometimes I go up and down to neighbors on a few floors above or below. (Man, 35-54, SDU)

The household structure of these low-income high-rise housing consists predominantly of young families with small children. Creating good opportunities for children to play in this form of housing is essential but not an easy task. Conflicts between resident groups occur when it is unclear where children are allowed to play.

> Sometimes, grandparents use elevators as play areas for their children, some even drop trash and waste in the lifts. Once I saw the elevators moving up and down repeatedly, it turned out that a grandma was pushing the up and down buttons to entertain her grandson so she could feed him. (Man, 35-54, SDU)
>
> On a hot day during summer, I want to open the door to get ventilation and extend the connection with the outdoor space, but children often play or cycle in the corridor and then make noise, some even run through the main door, curiously looking inside. Thus, I often close the door, but it is stuffy inside the apartment. (Woman, 35-54, Dai Thanh)

There is no open space around the SDU building. For residents at a younger age, walking to lakes/parks within 500-800 meters might not be a problem. However, for older residents who have mobility difficulties, it is a real challenge to have a long walk on a daily basis.

> I have difficulty walking so I can almost never walk somewhere further than the building. But, sadly, this building does not have open space for us to socialize. Every day I just push my husband's wheelchair around the lift lobbies and sometimes sit in front of the main hall for fresh air. I mostly stayed at home and did not socialize with her neighbors. (Woman, 83, SDU)

People in Kien Hung also report the organization of parties such as year-end parties, birthdays, etcetera. The corridor is also used as a place for social gatherings or play areas for cycling or playing football (see Figure 2).

> Sometimes after dinner, I and some men bring moveable chairs to the end of the corridor or the stair lobby to hang out, drink tea, or play chess.” (Man, 35-54, Thanh Ha)

Figure 2. Long corridors are used for different social activities (1) Dai Thanh (2) Kien Hung

During the survey, the authors observed one household that lives next to the side of the lift lobby decorated the lobby as a reception for a family member's wedding (Figure 3a), and during Christmas 2021 one resident

sent the authors photos of Christmas decoration in the corridor and lift lobby (Figure 3b). People also put plants or vegetable pots and place them in the corner of the corridor.

Figure 3. Corridors and lift lobbies are decorated for the wedding and Christmas in SDU.

For people who value privacy, these spontaneous social interactions can lead to discomfort and annoyance.

> Well, children cycling, playing football, hitting balls at the wall, making noise in the corridors...corridors are for circulation, not a play space. (Woman, 18-34, Dai Thanh)
>
> I do not support the idea of the corridors party. People even have hot pots in the corridors, the smell of food and the cooking is not safe and very annoying. Sometimes they even sing karaoke, obstructing traffic. (Man, 35-54, Thanh Ha)

3.2.1.2. The use of shared facilities for social interaction

The shared facilities in Kien Hung were provided in the form of space for meetings and events but were then converted by the residents into spaces for exercise, table tennis to be particular, though these spaces are quite limited. Services and amenities in the area are also limited since it is located in the expanded Hanoi urban area, which is about 3-4 km from the center of Ha Dong district.

> The buildings and neighborhood lack facilities; my husband needs to travel for 20-30 minutes to go to the gym. (Woman, 34-54, Kien Hung)
> I and a few women formed a group and organized yoga classes at the one end of the corridor early in the morning, around 5 am. (Woman, 18-34, Kien Hung)

A fixed function did not seem to work well for residents. With the densely populated living environment like apartment living, especially high-rise apartment buildings with limited land area, creating more flexible, adjustable, and various small, shared spaces interspersed with apartments.

> The common room on the ground floor used to be an open space for children to play but is now closed and used only for meeting purposes. However, this space is only used once every 2 to 3 months. The entire 2nd floor is now used for shared facilities. Since the building has no outdoor space surrounding it, it would be more practical if the common room on the ground floor could be left open and expanded into an open public space. (Woman, 55 or older, SDU)

In the Thanh Ha complex, the communal spaces for 3 buildings are located on the 2nd floor of the HH03A buildings. It is designed for community activity for the 3 buildings. Nonetheless, interviewees either have never used this space for any social activities or have just been one in the community meeting.

> Shared facilities were designed with closed doors and were used for meetings only. There is also no direct connection from the other 2 buildings to this space. The layout design of apartments on the same floor and without separation from public facilities causes obstacles to public space users and inconvenience to residents of these apartments. (Man, 34-54, Thanh Ha)

3.2.1.3. The use of outdoor space for social interaction

The study was conducted in the summer when the temperature was quite high, usually 30-40 degrees Celsius. People rarely gather outside the buildings during the day. Only in the early morning (before 7 am) or late afternoon (after 6 pm), mothers or grandmothers sit and let the children play in the courtyards around the buildings.

> The apartment unit is separated from the outside space by a closed wall, and people have no spatial or visual connection with the outside. Many of my neighbors are just locked behind the wall. I am not an indoor person, and since the weather is very warm and lacks ventilation

in the summer, I prefer to go down with my son for a short walk in the evening, sitting down to enjoy the fresh air and relax. (Man, 18-34, Kien Hung)

It is very hot in summer within the apartment unit and building, however, there are no trees or shaded roofs for seating or walking paths surrounding the building. (Woman, 34-54, Dai Thanh)

Figure 4. The main entrances in Kien Hung have modest transitions via steps and are surrounded by walkways with set-up seating

Older people claimed that residents are mostly young people who work all day, and children go to school. Old people don't have an appropriate space to socialize (play chess, talk, etc) or just sit comfortably.

My husband sometimes plays chess with other men on the sidewalk or in the small tea shop along the roadside. They don’t have a proper space to sit and place, sometimes just sit on their slippers or a piece of paper.” (Woman, 55 or older, Kien Hung)

We, people with similar interests in volleyball, get up very early in the morning when there is almost no traffic on the internal streets to play. (Woman, 55 or older, Kien Hung)

During the day it's hot outside, so I usually just stay inside the apartment, only occasionally going to the neighbor's house. When it's cooler in the evening, I accompany my grandson to the open yard in front of the building and take the opportunity to interact with the other women. We usually don't have appointments, but around dinner time we come down here to sit on the bench, play with our grandchildren, and talk. (Woman, 34-54, Kien Hung)

The immediate surroundings of the residential block or the spaces between buildings are known as appropriate spaces for social interaction (Gehl, 2011). SDU building has no outdoor space, therefore a small tea shop and a convenience store in front of the building's entrance along the old residential area have become places for people (especially men) to communicate and get acquainted. Most of the men said they knew their neighbors in the small tea shop.

3.2.2. Design elements that affect privacy and social interaction.

The findings reveal the effects of group size on privacy and social interaction. In a small group of apartments sharing one corridor, respondents perceived the corridor as an extension of their home. A group of apartment units at one end of the corridor or a group of apartment units sharing a short part of the corridor created a close group of neighbors (see Figure 5).

> The formation of small groups of apartments makes us perceive the corridor as a part of our apartment, where social interaction can be regulated and protected from passers-by. (Man 34-54, SDU)
> I often interact with people on the same side of the lift lobby but rarely with people from the other corridor. In a smaller group of households, I feel more familiar and, therefore, keep more close contact. (Woman, 18-34, Dai Thanh)

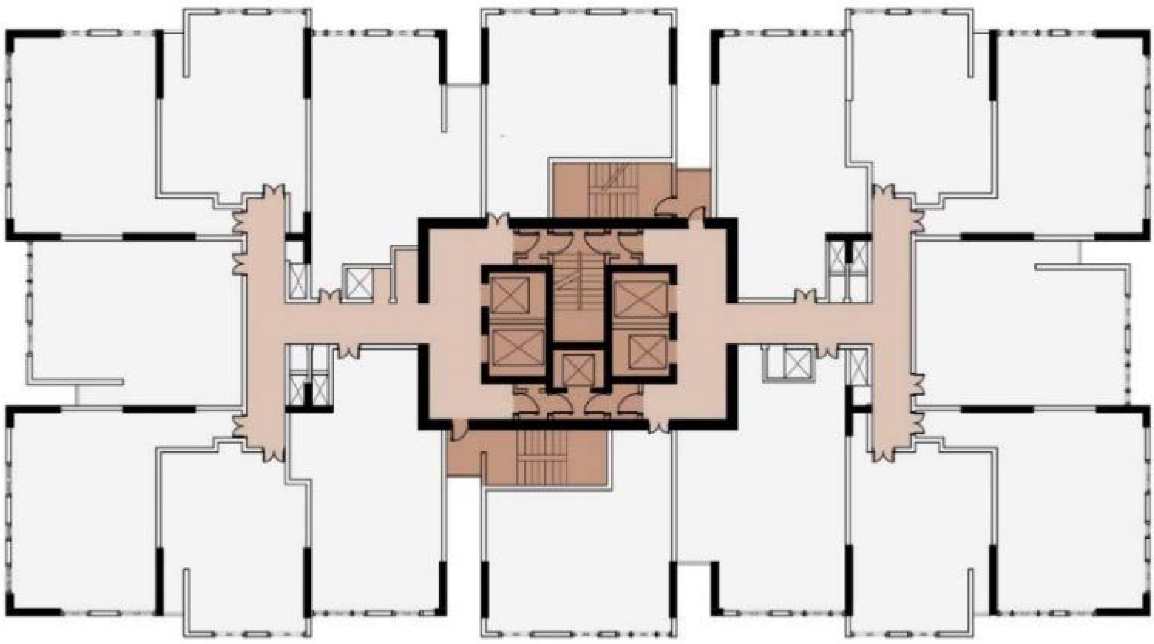


Figure 5. Typical floor_ SDU clusters of 2 to 3 apartment units at one end of the corridor

In a larger group setting (long corridors) the interviewees reported unwanted interaction.

> The building has a long corridor with many households, there is no transition between the private home and shared open spaces, and the corridors act as semi-public spaces. In my opinion, the transition area is important for residents to keep in contact with a nearby neighbor while at the same time keeping privacy. (Man, 18-34, Kien Hung)

I could not be able to predict or determine the nature and frequency of social contacts. Therefore, the encounters with neighbors in the corridor sometimes become unexpected and inconvenient." (Man, 35-54, Thanh Ha)

To improve privacy and safety while still ensuring connection between spaces inside and outside the apartment, the main doors of apartment units were renovated. Owners renovate the apartments with two-layer doors, the outer layer is a steel grille door, and a solid wooden layer door is on the inside (see Figure 6). The living room of each apartment unit and the common corridor can spatially emerge with one other, creating a spatial domain for interaction, exchange of help, or sharing goods.

If we are at home, we might open both doors or only open the wooden door and lock the outer steel grille door to provide ventilation and visibility in and out apartment unit. The steel grille door also plays a role in ensuring the safety of the apartment. (Man, 18-34, SDU)

Figure 6. Two-layer doors create visibility and provide ventilation for an apartment unit.

In the SDU building, there is only one entrance connected to the two separate lift lobbies on the ground floor through the main hall. They are small, with bad lighting and ventilation. Figure 7 presents photos that were taken by the author around 7 p.m. in the summer of 2019. People are jammed in a small and hot lift lobby

(Figure 7). Some people said sometimes they need to wait for 5 to 10 minutes to go into the lift during rush hours. The lift lobbies are hot and they feel tired therefore having no intention of talking with others.

Figure 7. Lift lobbies on the ground floor in SDU during rush hours

In Dai Thanh, Thanh Ha, and Kien Hung the lift lobbies on the ground are connected and extend through the main entrance, common corridor, and side entrance. The hallway and the lift lobbies on the ground have better ventilation. The main entrance and side entrance in Thanh Ha is connected straight to each other through the main hall. The ventilation and lighting are good. Ceiling and wall-mounted fans are provided within the main hall and lift lobbies in Thanh Ha and Kien Hung. Small children were playing in these areas. It is the same for Dai Thanh. People sometimes stop by and have conversations with others while waiting for the lifts. This is probably due to the wider and better ventilation design. There they can have a small chat/talk with neighbors (Figure 8).

Figure 8. Lift lobbies on the ground floors (1) Kien Hung (2) Thanh Ha (3) Dai Thanh

In Thanh Ha, the lift lobby on the ground floor opens to the shared courtyard through the side entrance without any buffer zone. The lift lobby therefore acts as a passway. This leads to overlapping traffic in front of the lift lobbies, affecting people's time waiting for the elevator, so people tend not to want to stop and talk to neighbors.

4. Discussion and conclusion

The research subjects of this study are low-income people. They have a comparatively larger tendency to look to interpersonal interactions with neighbors who are similar to them when it comes to laying the groundwork for their lives. Therefore, social interaction in the neighborhood plays a very important role in their lives. Nonetheless, low-cost high-rise apartments provide fewer meeting spaces and public facilities compared to high-end apartments. The lack of these spaces and facilities leads to some people's way of life and behavior not being suitable for the modern living environment of high-rise housing.

Creating opportunities and spaces to socialize, especially for children to play, in high-rise buildings is essential. If buildings or residential areas do not provide suitable space for this target group, it may lead to social annoyance among residents. Or, many children are kept inside and have little opportunity to go out to play and socialize with friends because. Since most households living in low-income high-rise buildings are small children's households, it is necessary to design play spaces for children (inside and outside the building) within sight of the parents or create opportunities for children to go out on their own. Creating a space for parents to sit, relax, or socialize close to the children's play spaces can also be considered. It even better if the designing of high-rise housing could also create opportunities for children to play without parental supervision.

Shaping the intermediate space is considered a great challenge, especially for the formation of open spaces to meet the scale of urban development and high-rise housing. The scale of high-rise housing required a lot more open spaces than what is provided now. Given the limitation of land in the city center, high-rise housing projects can consider the horizontal and vertical extensibility of common spaces. In modern apartment buildings, specifically, the inner-city high-rise building, outdoor areas just outside apartment units can act as the extension. Within the apartment unit, the living room is a common space, which can be a transition space between private living space and outdoors. Therefore, we can consider the interference between the connection between the common living space in the house and the floor corridor space. For projects located on the city fringe, it can be seen that, for hot and humid climates like Vietnam, especially in summer, providing open spaces in the immediate surroundings with seating areas is not enough, it is necessary to consider creating shade from trees or canopies for seats that were appreciated by residents. A promenade or sidewalk path in the neighborhood with shading is also important.

The ground floor of a high-rise building is the largest common space of the building. For investors, leasing these spaces for stores brings economic benefits. Therefore, the ground floor is fully utilized for rent and there is almost no space left for common public space. With the limitation of inner-city land, it can be an option to design the ground floor of the building that can be extended to the open spaces surrounding the buildings. Another option can be arranging common spaces alternating between floors. It is best to provide spaces in the building where only a limited number of residents meet. Residents should also be facilitated to use the circulation areas (e.g. corridors, lift lobby, and staircase landings) as transitional areas, inviting them to get out of their private apartments and socialize with others. Common public spaces need to be brought closer to people, creating many small groups of spaces that can encourage people to use them while still ensuring privacy for the apartments. This needs to be properly considered during the design process to be suitable for investment.

Central corridors in apartment buildings are commonly used for a variety of social interactions. Clustering residents that feel familiar with each other may also help to stimulate social interaction. The length and shape of the central hallway can have an impact on social activities. The clustered and/or divided corridor appears to have better control over social interactions than the corridors running the full length of the building.

References

Abdul Aziz, A., & Ahmad, A. S. (2017). Flat Layouts and Children Outdoor Ac vi es. Asian Journal of Environment-Behaviour Studies, 2(3), 57–66. https://doi.org/10.21834/aje-bs.v2i3.189

Abdul Aziz, A., Ahmad, A. S., & Nordin, T. E. (2017). Flats Outdoor Space as a Vital Social Place. Asian Journal of Environment-Behaviour Studies, 2(5), 39. https://doi.org/10.21834/aje-bs.v2i5.221

Abu-Ghazzeh, T. M. (1999). Housing layout, social interac on, and the place of contact in Abu-Nuseir, Jordan. Journal of Environmental Psychology, 19(1), 41–73. https://doi.org/10.1006/jevp.1998.0106

Al-Jokhadar, A., & Jabi, W. (2016a). Enhancing Social-Cultural Sustainability in Tall Buildings: A Trace from Vernacular Houses. Cities to Megacities: Shaping Dense Vertical Urbanism: A Collection of State-of-the-Art, Multi-Disciplinary Papers on Urban Design, Sustainable Cities, and Tall Buildings. Proceedings of the CTBUH 2016 International Conference; China, 633–641.

Al-Jokhadar, A., & Jabi, W. (2016b). Towards a ‘Contemporary Vernacular’ High-rise Residen al Development in the Middle-East and North-Africa: Learning from the Socio-Spa al Quali es of the Vernacular Model. The 5th International Jordanian Architectural Conference: Contemporary Architecture in the Arab World, Jordan (1-3/11/2016), 1(November), 1–12. https://orca.cf.ac.uk/92009/1/Jordan Conference - Al-Jokhadar.pdf

Choi, J., Kim, Y., & Kang, J. (2013). Study on the Applica on of Vernacular Design to High-rise Apartment Planning in Vietnam. Architecture Science, 8, 11–18.

Choi, J., Kim, Y., Kang, J., & Choi, Y. (2014). Compara ve analysis of the spa al structure of apartment unit plans in Asia - Apartments in Korea, Vietnam, And kazakhstan -. Journal of Asian Architecture and Building Engineering, 13(3), 563–569. https://doi.org/10.3130/jaabe.13.563

Clarke, V., & Braun, V. (2017). Using thema c analysis in psychology. Journal of Positive Psychology, 12(3), 297–298. https://doi.org/10.1080/17439760.2016.1262613

Costello, L. (2005). From prisons to penthouses: The changing images of high-rise living in Melbourne. Housing Studies, 20(1), 49–62. https://doi.org/10.1080/0267303042000308723

Dinh, Q. P. (2011). The impact of “informal” building addi ons on interior/exterior space in Hanoi’s old apartment blocks (KTT). Diversity and Connectedness as the Flexibility of Built Environments Architecture in the Fourth Dimension Methods and Practices for a Sustainable Building Stock, 131–138.

Francis, J. J., Johnston, M., Robertson, C., Glidewell, L., Entwistle, V., Eccles, M. P., & Grimshaw, J. M. (2010). What is an adequate sample size? Opera onalising data satura on for theory-based interview studies. Psychology and Health, 25(10), 1229–1245. https://doi.org/10.1080/08870440903194015

Geertman, S. J. L. (2007). The self-organizing city in Vietnam : processes of change and transforma on in housing in Hanoi LK - https://tue.on.worldcat.org/oclc/8087183252. In TA - TT -. Technische Universiteit Eindhoven SE -.

Gehl, J. (2011). Life Between Buildings: Using Public Space. Island Press. https://books.google.nl/books?id=X707aiCq6T8C

Gifford, R. (2007). The consequences of living in high-rise buildings. Architectural Science Review, 50(1), 2–17. https://doi.org/10.3763/asre.2007.5002

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Satura on and Variability. Field Methods, 18(1), 59–82. htps://doi.org/10.1177/1525822X05279903

Karsten, L. (2022). Young Families and High-Rise: Towards Inclusive Ver cal Family Housing. Urban Planning, 7(4), 245–252. htps://doi.org/10.17645/up.v7i4.5624

Maguire, M., & Delahunt, B. (2017). Doing a Thema c Analysis: A Prac cal, Step-by-Step Guide for Learning and Teaching Scholars. Journal of Teaching and Learning in Higher Education, 8(3), 3351–3359. http://ojs.aishe.org/index.php/aishe-j/ar cle/view/335%0A

Ministry of Construc on. (2006). High-rise building – Geography survey (14 /2006/QD-BXD).

Modi, S. (2014). Improving the social sustainability of high-rises. International Journal on Tall Buildings and Urban Habitat-CTBUH Journal, 1, 24–30.

Moore, S., Bockenholt, U., Daniel, M., Frohlich, K., Kestens, Y., & Richard, L. (2011). Social capital and core network es: A valida on study of individual-level social capital measures and their associa on with extra- and intra-neighborhood es, and self-rated health. Health and Place, 17(2), 536–544. htps://doi.org/10.1016/j.healthplace.2010.12.010

Muhuri, S., & Basu, S. (2021). Interac onal spaces of a high-rise group housing complex and social cohesion of its residents: case study from Kolkata, India. Journal of Housing and the Built Environment, 36(2), 781–820. htps://doi.org/10.1007/s10901-021-09830-3

Nguyen, K. H. (2016). Towards developing a design model for socially sustainable multi-storey housing in Vietnam: an environment-behaviour approach. RMIT University.

Nguyen, L. P. M., van den Berg, P. E. W., Kemperman, A. D. A. M., & Mohammadi, M. (2024). Social impacts of living in high-rise apartment buildings: The effects of buildings and neighborhoods. Journal of Urban Affairs, 1–22. htps://doi.org/10.1080/07352166.2024.2311165

Nguyen, L., van den Berg, P., Kemperman, A., & Mohammadi, M. (2020). Where do people interact in high-rise apartment buildings ? Exploring the influence of personal and neighborhood characteris cs. International Journal of Environmental Research and Public Health, 17(13). htps://doi.org/htps://doi.org/10.3390/ijerph17134619

Ridwana, R., Prayitno, B., & Utomo Hatmoko, A. (2018). The Rela onship Between Spa al Configura on and Social Interac on in High-Rise Flats: A Case Study On The Ja negara Barat in Jakarta. SHS Web of Conferences, 41, 07003. htps://doi.org/10.1051/shsconf/20184107003

Siew Bee, A., & Poh Im, L. (2016). The provision of ver cal social pockets for beter social interac on in high-rise living. Journal of the Malaysian Institute of Planners, 14(Special Issue 4), 163–180. htps://doi.org/htps://doi.org/10.21837/pm.v14i4.156

Thompson, S. (2021). Creating Better Shared Spaces in APartment Complexes and their Local Areas. Ci espeoplelove.Co. htps://ci espeoplelove.co/ar cle/crea ng-beter-shared-spaces-in-apartment-complexes-and-their-local-areas

Webb, B., & White, J. T. (2022). Planning and the High-Rise Neighbourhood: Debates on Ver cal Ci es. Urban Planning, 7(4), 208–212. htps://doi.org/10.17645/up.v7i4.6357

Wu, W., & Ge, X. J. (2020). Communal space design of high-rise apartments: A literature review. Journal of Design and Built Environment, 20(1), 35–49.

5 Citizen science, smart art & place making: **Abstract livinglab DEEL**

The Art of Connection
Advancing public familiarity in the neighbourhood through an interactive artwork

Masi Mohammadi[1*], Gerald Gosselink-Ramos[1], Sophie Peters[1]

[1] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

*Corresponding author: Masi Mohammadi (masi.mohammadi@han.nl)

The consequences of the changing society emphasize the importance of an informal (care) network within the living environment. However, amplifying or establishing local social networks is not straightforward. To lower the threshold, instead of focusing on deep-rooted networks, public familiarity could be highlighted. Repeated social interactions, which can be accessible and fleeting in nature, add up to establishing mutual trust and a sense of home and community in the neighbourhood.

The project The Art of Connection connects knowledge institutes, artists, and residents to investigate interactive art in the neighbourhood Stadseiland in Arnhem as a catalyst for accessible encounters. How can an interactive artwork in semi-public space stimulate and facilitate social interaction between residents? By actively involving the residents and other (local) stakeholders throughout the entire project, a learning community is formed that increases the chance of a successful intervention. In addition, this involvement is not only aimed at bringing the artwork to a successful conclusion, but at connecting the residents of Stadseiland during the process itself as well, by supporting new interactions and deepening existing contacts during research activities.

The design process of developing a prototype of the artwork consisted of two iterations. The first iteration started with exploratory research, including a walking interview, spatial analysis, demographic desk research and introductory conversations with various resident groups and local professionals. Subsequently, small groups of representative residents were identified and involved. Next, their input resulting from creative co-creation sessions and co-reflection sessions was translated into an Augmented Reality (AR) prototype. In the second iteration, the neighbourhood on a larger scale could participate, by reflecting on the AR prototype during a fair in the local park. Their feedback was translated and expressed into a physical prototype.

The process resulted into the design of an interactive and movable artwork, where people can share their voices and visions with the neighbourhood, vocalized and translated into bird calls and visualized with the help of AR. In the following and concluding phase of the project the prototype will be tested and validated.

Partners: Fillip Studios, Fontys, ArtEZ, Camp Matrix, Energy Floors, Rijnstate, Municipality of Arnhem, DEEL

Funded by: Dutch Research Council under the Taskforce for Applied Research SIA Extramuralisation program

Start date LivingLab: September 2021
End date LivingLab: July 2024

5 Citizen science, smart art & place making: **Abstract livinglab DEEL**

It Takes a Village to Grow Old

Masi Mohammadi[1], Leonie van Buuren[1], Barbara Groot[2], Tamar Shahinian[2], Marja Peltenburg[3], Marlene Hoynck[3], Somaya Ben Allouch[4], Saskia Robben[4], Marwan Al Morabet[4], Ivor Swaab[5]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Leyden Academy on Vitality and Ageing, The Netherlands

[3] Stadsdorp VondelHelmers, The Netherlands

[4] Research Group Digital Life, Amsterdam University of Applied Sciences, The Netherlands

[5] Illi-tv, The Netherlands

*Corresponding author: Masi Mohammadi (masi.mohammadi@han.nl)

To age in place, recurring encounters in the neighbourhood could be beneficial for citizens (with dementia). Public familiarity deals with this phenomenon and the design of the physical environment – especially so-called 'fourth places' – could contribute to this, for example by using conversation starters. These conversation starters could be smart art objects which stimulate encounters. However, it is irregular to design such stimulating smart art objects with local citizens. And if doing so, often dilemmas arise where democratic participation is at stake. The aim of this living lab was to study the development of smart art objects in fourth places to stimulate social encounters using a citizen science approach. We explored the dynamics between smart art objects, place-making, and social health.

Participatory action research was integrated in the Empathic Design Framework in three iterations in a specific neighbourhood in Amsterdam: VondelHelmers. A mixed method approach was used to explore the needs, preferences, and possibilities of socio-spatial factors (e.g., diary study, photovoice, preference study), to develop design solutions (e.g., design workshops), and to evaluate the design solutions (e.g., observation, group interviews).The involvement of citizens in this process was layered: co-deciding members of the project team, consulting members of a task force, and consulting and informing a broad group of citizens. The first two groups were actively involved in conducting the research (e.g., interviewing, observing).

The developed smart art object in the neighbourhood VondelHelmers is a sheltered bench, with the possibility to exchange neighbourhood stories, both digitally (smart tablet) as with physical objects (in a showcase cabinet). First experiences with this smart art object are positive; citizens showed curiosity behaviour towards the art object. In addition, during the research and

development process, involved citizens mentioned more conversations, even with neighbours they did not know before (i.e., public familiarity).

Partners: TU/e, Stadsdorp VondelHelmers, LA, HvA, UvA, illi-tv, WG-kunst, Cliëntenbelang Amsterdam, Stichting Mantelzorg & Dementie

Funded by: Health~Holland & ZonMw

Start date LivingLab: 04.04.2022
End date LivingLab: 03.10.2024

5 Citizen science, smart art & place making: **Abstract workshop**

Challenges to d(HL) in Europe and how to overcome them perspective from citizens with a focus on the older adults in Italy

Oscar Zanutto, Adele De Stefani

on behalf of the IDEAHL Consortium

ISRAA

faber@israa.it

The increasing digitalisation of health services, health-related communication and, in some cases, even treatment is a reality that the European population is currently facing. Digitalisation of health poses several challenges with regard to daily health management, especially when it comes to population segments that are more exposed to frailty and marginalisation. Therefore, ensuring citizens' digital health literacy is becoming crucial to guarantee equal access to health and wellbeing, paying particular attention to those at risk of exclusion. Moving from the results of the consultation conducted within the Horizon Europe IDEAHL project with 1434 citizens belonging to different population groups in 10 EU countries, the presentation gives an overview of the main challenges they encounter when seeking information or taking action to manage their health, especially when using the Internet, online platforms, and apps. A special eye is devoted to the Italian panorama and the case of the Italian over-65s. The presentation dwells on the emerged challenges, which allow the identification of the aspects it is a priority to act on in order to increase European population d(HL) and prevent digitalisation from aggravating already existing health inequalities.

"The project "Improving Digital Health Empowerment for Active Healthy Living (IDEAHL)" has received funding from Horizon Europe Framework Programme under GA 101057477"

5 Citizen science, smart art & place making: **Abstract workshop**

Neighborhood Social Interaction. How can buildings and the immediate surroundings of the housing estate support social interaction? (EN)

Linh Nguyen[1*], Pauline van den Berg[2*]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Fontys University of Applied Sciences, The Netherlands

* Corresponding authors: Linh Nguyen (p.m.l.nguyen@tue.nl) and
Pauline van den Berg (p.vandenberg@fontys.nl)

Social interaction between neighbors is more than just recognizing one another's faces, it is about communicating with each other, participating in common activities, and lending a hand to one another. Interacting with neighbors such as exchanging interests or having small conversations could increase people's happiness, health, and well-being. With a certain level of social interaction, people can have the feeling of being socially integrated which could decrease the feeling of loneliness. Without interaction with neighbors, residents are considered as a group of people living separate lives in their neighborhood. One may ask if and how the design of the building and the immediate surroundings can invite residents to stay longer outside their private territories and as a result, support interaction among fellow neighbors.

This workshop aims to emphasize the importance of social interaction and inclusivity within the neighborhood. We would like to highlight the perspectives of researchers and architects on the importance of buildings and the immediate surroundings to people's social interactions. We also want to open a discussion with experts in different disciplines such as researchers, designers, housing associations, project developers, policymakers, etc. on how the design of buildings and the immediate surroundings can stimulate residents' social interaction within a neighborhood.

The main question of this workshop session is: How can the design of housing and the direct living environment contribute to more social interaction and a reduction in loneliness i.e. what spatial features create opportunities for social connection?

In this workshop, we will discuss this topic with experts from different backgrounds. First, the topic will be introduced in three presentations. Next, we will have a group discussion to further reveal which spatial features create opportunities for social connection.

6

Indicated health & smart health

6 Indicated health & smart health: **Conference paper**

Guiding Dynamic Adaptive Decision Making

a quasi-experimental study in healthcare

Anke Aarninkhof-Kamphuis[1]*, Hans Voordijk[1], Geert Dewulf[1]

[1] University of Twente, The Netherlands

Corresponding author: Anke Aarninkhof-Kamphuis (a.m.aarninkhof@utwente.nl)

Abstract: More than ever before, healthcare decision makers have to be aware of deep uncertainties affecting the future needs of their clients. While using the concept of stewarding capacity, the objective of this study is to assess to what extent the use of a Dynamic and Adaptive Decision Support model (DADS) provides strategic decisions makers of healthcare organizations the capacity to cope with and anticipate future change, uncertainty and risk in the long term. The pandemic of Covid-19 led to a different Program of Requirements for an organization, affecting the development process of a new building under construction. Changing governmental policies for long-term care influences an organization's care process, leading to a different real estate strategy. A quasi-experimental design study is conducted at a healthcare organization during the process of formulating their healthcare real estate strategy. It is confirmed that DADS contributes to an increasing awareness of deep uncertainty and increasing awareness of adaptive pathway planning among strategic healthcare decision makers. Also the stewarding capacity effects of DADS, including the generating of knowledge for the healthcare organization, empowering healthcare decision makers and their organization across multiple scales and encouraging monitoring and continuous learning was revealed.

Keywords: dynamic adaptive decision-making, stewarding capacity

1. Introduction

Strategic decision-making at healthcare organizations has to constantly adapt to changing circumstances. More than ever before, healthcare decision makers have to be aware of the deep uncertainties affecting the future needs of their clients. Especially when taking long-term decisions, e.g. in healthcare real estate, dynamic adaptive decision-making and the guiding ability of decision makers are essential.

Earlier research has been written on Decision Making under Deep Uncertainty (DMDU) and elaborate on promising dynamic adaptive approaches (Lempert, Groves, Popper, & Steve C.

Bankes, 2006; Marchau, Walker, Bloemen, & Popper, 2019; Scholte et al., 2023). Deep uncertainty requires policies based on the paradigm of 'prepare, monitor, and adapt' so that policies can be adjusted over time as events occur and more knowledge is gained (Hadjisotiriou, Marchau, Walker, & Rikkert, 2023). The underlying paradigm of these DMDU approaches is the need for measures to reduce the vulnerability of a policy or strategy to uncertain future developments.

Also in healthcare management former studies were published to support decision makers and their organizations in strategic decision-making (Maki, Alshaikhli, Gunduz, Naji, & Abdulwahed, 2022; Nunes-Vaz, 2019; van der Voordt, 2016; Van Reedt Dortland, Voordijk, & Dewulf, 2014; Zwart, 2014). Decision makers of healthcare organizations face deep uncertainties when taking strategic decision e.g. during the development and realization of their facilities due to technological, economic, social, and political developments (Hornung & Bandelow, 2022; Mackintosh & Armstrong, 2020) and hence anticipate future environment transformations (Aarninkhof-Kamphuis, Voordijk, & Dewulf, 2023; Haasnoot, Warren, & Kwakkel, 2019; O'Mara, 1999). For this purpose, we developed a Dynamic and Adaptive Decision Support model (DADS) for healthcare organizations facing deep uncertainty in a rapidly changing healthcare environment and dealing with strategic decision-making.

To study how the use of the DADS can strengthen healthcare decision makers with dealing with deep uncertainties, we focus on the concept of stewarding capacity (Hölscher, 2019). Stewarding capacity enables anticipation and response to disturbances, risks and uncertainty (Hölscher, 2019). It makes healthcare decision makers more aware of deep uncertainty and its impact on making informed long-term decisions. Therefore, we want to measure and understand the ability of healthcare decision makers; 1. when applying the DADS during a strategic management process in a quasi-experimental study; 2. whether the use of this DADS leads to an increased awareness of deep uncertainty in making informed long-term decisions; and 3. while using the concept of stewarding capacity as an indicator of coping with and anticipating change, uncertainty and risk in the long term (Hölscher, 2019). Therefore, the core question is: "What are the stewarding capacity effects of applying DADS for healthcare decision makers?"

First, DADS is presented and stewarding capacity effects in an organizational context are examined in a conceptual framework in Section 2. Third, the methodology of this quasi-experimental study is explained. Section 4 describes the preliminary results of this study. Section 5 discusses the findings, followed by conclusions.

2. Conceptual Framework

A Dynamic Adaptive Decision Support model (DADS) is built to support an organization's strategic decision-making process in dealing with deep uncertainties. The concept of stewarding capacity introduced by Hölscher (2019) is used to assess to what extent the use of this model by strategic decisions makers of healthcare organizations provides the capacity to cope with and anticipate future change, uncertainty and risk in the long term.

Figure 1. Design of Dynamic Adaptive Decision Support model (DADS) for a healthcare organization

2.1 Stewarding Capacity

Stewarding capacity is defined as the ability to anticipate, protect and recover from on-going changes, uncertainty and emerging risks, stresses and surprises while creating opportunities beneficial for resilience (Chapin et al., 2010; Folke, Biggs, Norström, Reyers, & Rockström, 2016; Hölscher, 2020; Hölscher, Frantzeskaki, & Loorbach, 2019). Stewarding capacity influences which and how disturbances are anticipated and what responses are enabled (Hölscher, Frantzeskaki, & Loorbach, 2020). It relates to notions of adaptability and adaptive governance that help governing complex systems when knowledge is incomplete (Chaffin, Gosnell, & Cosens, 2014; Chapin et al., 2010; Folke, Hahn, Olsson, & Norberg, 2005; Hölscher, 2020). Conditions for stewarding are created by developing knowledge on systemic risks and uncertainties, establishing integrated, long-term and multi-level planning approaches, and supporting complex social networks of urban services e.g. housing, jobs, health systems, and finance (Hölscher, 2020; Torabi, Dedekorkut-Howes, & Howes, 2018). Key challenges include enabling adaptation into planning decisions at national, regional and local levels (Hölscher, Frantzeskaki, & Loorbach, 2020).

Hölscher (Hölscher, 2019, 2020) mentioned three subfunctions of stewarding capacity: (a) generating knowledge and integration about system dynamics; (b) strengthen self-organization across multiple scales; and (c) ensure monitoring and continuous learning. In this study, the stewarding capacity subfunctions are used to assess to what extent the use of DADS provides strategic healthcare decisions makers the capacity to cope with future deep uncertainties.

2.2 Generating knowledge about system dynamics

According to Hölscher (2020), generating knowledge about system dynamics across scales enables the anticipation of emergent risks and uncertainties (Chapin et al., 2010; Folke et al., 2016; Hölscher, 2020). Diverse partnerships between actors from academia, local, regional and national governments and local communities support the generation and co-production of knowledge (Hölscher, Frantzeskaki, McPhearson, & Loorbach, 2020; Molenaar, Hölscher, Loorbach, & Verlinde, 2021). Hölscher (Hölscher, 2019, 2020) addressed the following aspects of generating knowledge about system dynamics:

1. Developing long-term systematic and context-specific knowledge about risks and uncertainties (Hölscher, 2020). Translated to healthcare, Snell and Morris (Snell & Morris, 2014) addressed this to three knowledge assets; human capital, social capital and organizational capital. The focus of this study is on developing knowledge about technological, economic, social or political developments as well as future healthcare transformations (Aarninkhof-Kamphuis et al., 2023) within and across an organization (Marion Kersten, 2024; MCO Kersten, Taminiau, Schuurman, Weggeman, & Embregts, 2018);

2. Formalizing and encouraging knowledge partnerships (Hölscher et al., 2020). Translated to healthcare, development of knowledge is on both abstract and strategic levels and takes place in collaboration with external partners such as other organizations, municipality, external experts etc. (Van Reedt Dortland et al., 2014);

3. Mandating knowledge generation to ensure access to data (Hölscher et al., 2020). Translated to healthcare, Boateng (Boateng, 2007) addressed the macro-, meso-, and micro-level healthcare decision-making. Each level has a distinct mandate, but all are linked to contribute to overall health care system performance. For this study we focus on the meso-level, where CEO and senior management in an organization working in collaboration with health care professionals and local stakeholders groups.

For an overview of activities and conditions for stewarding capacity (Hölscher, 2020), and the translation to the healthcare context, see Table 1.

Table 1. Activities and condition of stewarding capacity translated to the healthcare context

Stewarding capacity sub-function	Activities and condition (Hölscher, 2020)	Translated to the healthcare context:
a. Generating knowledge about system dynamics	1. Developing long-term, systemic and context-specific knowledge about risks and uncertainties (knowledge condition)	Knowledge is embedded within people, relations, and organizational routines with three knowledge assets: human capital, social capital and organizational capacity Identifying unforeseen impact on the organization and interorganizational norms and networking
	2. Formalizing and encouraging knowledge partnerships (network condition)	Realizing that knowledge is on both abstract and strategic levels, something that is needed to translate strategic issues in collaboration with external partners
	3. Mandating knowledge generation to ensure access to data (institutional condition)	With a focus in this study on the meso-level, where CEO and senior management in an organization working in collaboration with health care professionals and local stakeholders groups
b. Strengthening self-organization across multiple scales	1. Integrating flexible, problem-based and fit-to-context planning and management approaches (institutional condition)	Integrating long-term risks and uncertainty into an integrated approach to support planning of strategic and tactical decisions
	2. Establishing multi-scale and cross-sectoral networks and partnerships for risk planning and management (network condition)	Multi-level management approach from a stakeholders perspective to define a long-term scenario and future strategies
	3. Social capital and actor empowerment (social condition)	Social capital building achieves outcomes by creating bonds within communities, connecting communities and linking communities to health and other social system decision-makers
c. Monitoring and continuous learning	1. Creating an institutional and social memory by drawing on past experience and learning about new solutions (knowledge condition)	Healthcare is a knowledge intensive industry, and knowledge management is an integral component in building learning healthcare organizations
	2. Creating an institutional and social memory by continuously updating plans and resilience indicators (knowledge condition)	A learning health system, specifically one that has the capacity to understand performance across the continuum of care and use that information to achieve continuous improvements in efficiency and effectiveness

2.3 Strengthening self-organization across multiple scales

According to Hölscher (2020), the second subfunction of stewarding is strengthening self-organization to support the abilities of organizations, communities and individuals to respond independently and flexibly to changes and disturbances (Dietz, Ostrom, & Stern, 2003; Folke et al., 2005; Hölscher, Frantzeskaki, McPhearson, et al., 2020). Hölscher (2020) addressed the following aspects of strengthening self-organization across multiple scales to respond to risk and uncertainty:

1. Integrating flexible, problem-based and fit-to-context planning and management approaches (Hölscher, 2020). Cardoso et al. (Cardoso, Oliveira, Barbosa-Póvoa, & Nickel, 2015) mentioned a scenario tree approach to reduce scenarios and solve the problem (Birge & Louveaux, 1997; Rafiee & Kianfar, 2011) e.g. focusing on a certain future event which leads to decisions to be taken. Also mathematical programming methods are considered, which have been employed to solve a variety of problems forming the real-world issue (Rafiee & Kianfar, 2011). These methods are based on scenario planning, and proposed an integrated approach to support planning of strategic and tactical decisions in the long term care sector, e.g. the location selection and capacity planning decisions;

2. Establishing multi-scale and cross-sectoral networks and partnerships for risk planning and management (Hölscher, 2020). Maillet et al. (Maillet, Lamarche, Roy, & Lemire, 2015) mentioned the multilevel governance emerges in the 1990s, and divide the organization into a clinical and administrative sphere. Pereno and Erikson (Pereno & Eriksson, 2020) addressed the multi-level management approach of a healthcare organization from a multi-stakeholders perspective in order to define a long-term scenario and future strategies. Sujan et al. (Sujan et al., 2017) addressed the need in health care to develop a regulatory framework and an agreed process for managing explicitly the trade-off between risk reduction and cost, i.e. organizations need to make decisions about whether or not to invest effort and resource in understanding and reducing risks to patient safety;

3. Creating social capital and actor empowerment (Hölscher, 2020). Translated to healthcare, Ogden et al. (Ogden, Morrison, & Hardee, 2014) mentioned social capital building achieves outcomes by creating bonds within communities, connecting communities to each other and linking communities to health and other social system decision-makers.

2.4 Monitoring and continuous learning

The third subfunction of stewarding capacity is to ensure monitoring and continuous learning; to strengthen social and institutional memory and reflexive learning mechanisms for continuous monitoring how the system responds to changing situations (Hölscher, 2019). This requires to foster learning partnerships and a collective social memory for linking past experiences with present and future (Hölscher, 2020). Hölscher (2020) addressed the following aspects of monitoring and continuous learning:

1. Creating an institutional and social memory by drawing on past experience and learning about new solutions (Hölscher, 2020). Translated to healthcare, Wickramasinghe (Wickramasinghe, 2008) addressed knowledge management is an integral component in building learning healthcare organization. Kersten (2024) mentioned the importance of a stimulating learning culture in healthcare organizations, in which professionals collaborate in self-steering teams.

2. Creating an institutional and social memory by continuously updating plans and resilience indicators (Hölscher, 2020). Translated to healthcare, Kraft et al. (Kraft et al., 2017) described a learning health system, specifically one that has the capacity to understand performance across the continuum of care and use that information to achieve continuous improvements in efficiency and effectiveness. Iflaifel et al. (Iflaifel, Lim, Ryan, & Crowley, 2020) addressed effective team relationships, trade-offs and health care 'resilience' training of health care professionals are factors used to develop resilient health care.

3. Methods

3.1 Quasi-experiment

The current study utilized a quasi-experiment to measure the stewarding capacity effects of DADS in a context-rich and controlled setting of strategic decision makers of a healthcare organization. Testing in a control-rich setting for 'internal validity' shows the effects of the intervention of DADS. Internal validity refers to the extent to which a study is capable of establishing causality (Handley, Lyles, McCulloch, & Cattamanchi, 2018). Testing in a context-rich setting for 'external validity' can contribute deeper insight into the effect of the intervention under real conditions (Franken-Champlin, 2019). External validity describes the extent to which a research conclusion can be generalized to the population or to other settings (Handley et al., 2018). The process of this quasi-experiment is shown in Figure 2.

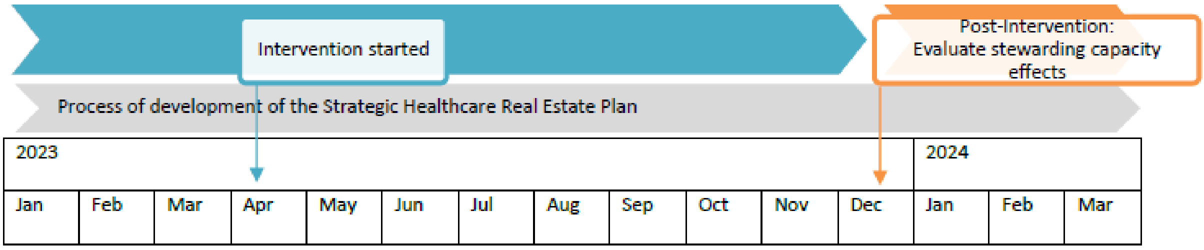


Figure 2. The process of the quasi-experiment

The quasi-experiment was conducted at a healthcare organization operating in a particular region of The Netherlands. This organization with about 4,000 care professionals is responsible for elder care of about 6,000 clients. The intervention was examined during the development of the Strategic Real Estate Plan for this organization. This is -mostly- a two-yearly strategic trajectory, where the organization determines the future real estate strategy. The main involved decision makers and care professionals in this quasi-experiment were: a board member, a care manager, a policy officer, a customer and market manager, a team leader and real estate manager (n=6).

3.2 Intervention

The intervention during the healthcare real estate management process started with the introduction of DADS to the real estate manager and management board of the healthcare organization. The total period of the intervention was about ten months. The researchers provided the set-up of the intervention, while the board management and real estate manager initially applied their knowledge of the organization and the real estate process.

3.3 Data collection

The used data consists of participatory observations during the Intervention phase, former Strategic Real Estate reports of the organization, conducting interviews after the Intervention. Through these approaches, we were able to triangulate data (Miles & Huberman, 1994). We also applied method triangulation (by participating in individual and group meetings, and collecting documents such as reports and meeting minutes), source triangulation (by interviewing and observing different participants, in different places, and at different times), and research triangulation (with the first two authors being able to discuss their observations while the third author was able to reflect on the observations with an outside perspective).

3.4 Data analysis

The data analysis is conducted by focusing on stewarding capacity effects during and after each session. Consequently, this leads to the preliminary results of the intervention and a further specification of the procedure of the DADS. This quasi-experimental study was finished with personal interviews of the involved main participants. The Interview Guide focused on measuring the stewarding capacity effects of the intervention by asking open questions. We coded the answers and categorized each relevant statement made during the interviews. After open and axial coding, a summary of the relationships between codes is conceptualized through selective coding (Boeije, 2002).

Further, we investigated former Strategic Real Estate Plan with the conceptual new model, also with a focus on generating knowledge, strengthening the organization and monitoring and continuous learning for the organization

4. Results and analysis

To measure the stewarding capacity effects of DADS, a total of 108 codes was grouped into three main categories: a generating knowledge about system dynamics; b. strengthening self-organization across multiple scales, and c. monitoring and continuous learning.

4.1 Generating knowledge about system dynamics

Most participants mentioned that the organization had no specific program to support the generation of knowledge. They announced that knowledge is embedded within people, relations and organizational routines. The organization is cooperating with different educational institutes in order to get latest knowhow on specific care organizational topics. In healthcare real estate, they follow market trends in new asset supply and demand of regions. There were no other programs in the organization that identify unforeseen impact on the organization or interorganizational norms and networking.

The intervention created mostly knowledge on awareness of uncertainty and beforehand thinking in different possible pathways to be adaptive for the uncertain future. The challenge for the future is to build bridges between care and real estate in order to smoothly act on the needs of clients. The integration of different disciplines (e.g. care and real estate) and long-term thinking during this strategic decision-making process was new for the organization. Another participant mentioned that the real challenge is to safeguard knowledge of construction or real estate processes for the future. Knowledge partnerships (as network condition) was only in initial stage setting up between real estate managers of different regional healthcare organizations.

4.2 Strengthening self-organization across multiple scales

The participants shared that there are no specific planning and management approaches across scales to support planning of strategic and tactical decisions responding on deep uncertainty and risks of real estate.

Managers support the board in strategic decision-making by focusing on the core process of delivering care, building bridges between external and internal stakeholders, and investing on care knowledge processes e.g. by regular meetings with the care professionals.

DADS brought the organization, in the opinion of the participants, a founded strategic procedure with potential future pathways. All involved care professionals were invited to act and think in strategic decision-making, which gave them -besides strengthening self-organization- also awareness of uncertainties, adapting tipping points and potential strategies. The opportunity for the organization is to cooperate with stakeholders, who can also facilitate in assets, e.g. housing corporations and/or investment companies. Participants mentioned the need to be independent of political change, by creating an adaptive healthcare organization.

4.3 Monitoring and continuous learning

Participants spoke about PDCA-cycles when asking about monitoring and continuous learning for the organization. Participants take responsibility for themselves and collaborate in self-steering teams, but have no specific memory by drawing on past experience and learning about new solutions. One participant mentioned the need for these kind of DADS modelling to safeguard knowledge of real estate projects.

The participants mentioned the need of a core team with the responsibility for a yearly monitoring and continuous learning for strategic real estate plans.

One decision-maker mentioned as most significant milestone, the external stakeholders meeting during this trajectory. Other participants mentioned the care managers meeting which brought a positive flow of awareness of deep uncertainties, but also the opportunities the organizations has. The challenge is to continuously updating plans and define the resilience indicators for the organization.

5. Discussion

This quasi-experimental study revealed that DADS helps the healthcare organization in generating knowledge about system dynamics, strengthening self-organization and in monitoring and continuously learning. The challenge is formalizing and encouraging knowledge partnerships with a network of stakeholders, who can also facilitate in assets, e.g. housing corporations and/or investment companies, but also knowledge partnerships between other healthcare organizations. For strengthening self-organization, DADS supports planning and management approaches, e.g. the collaboration between general organizational, human, learning, physical and financial resources and capabilities (Harrison & Thompson, 2014) in order to further support strategic and tactical decision-making. For monitoring and continuous learning, the yearly update of the real estate strategic plan and definition of resilience indicators are necessary.

6. Conclusion

The main objective of this study is to validate the developed DADS model for healthcare organizations facing deep uncertainty by considering the stewarding capacity effects. This quasi-experimental study confirms that DADS contributes to an increasing awareness of deep uncertainty and increasing awareness of adaptive pathway planning among healthcare decision makers. Also the stewarding capacity effects in terms of generating knowledge, empowering self-organization across multiple scales and encouraging monitoring and continuous learning was revealed.

A recommendation is to develop an expertise center or strengthen a learning community to support healthcare decision makers dealing with increasing (deep) uncertainties and dynamic adaptive decision-making. Regular dynamic adaptive pathway studies in and for healthcare organizations could be more institutionalized to be better prepared for the future.

In terms of the reliability and generalizability of the findings, the first point to note is that the data are limited to the experiences of one healthcare organization. Given the longitudinal and ethnographic design of the study, only a limited number of interviewees were conducted. However, as the respondents represent a large number of employees and clients and the long-term period of observations, the external validity of these findings should be reasonably high. Nevertheless, a certain amount of subjectivity may be present in the way the questions have been interpreted by the respondents.

Further research is needed on the intervention effects of the decision support model to other healthcare organizations, e.g. disability care organizations and hospitals.

Acknowledgements

The authors express their gratitude to Van Aarle De Laat Consultancy for supporting this study.

References

Aarninkhof-Kamphuis, A., Voordijk, H., & Dewulf, G. (2023). Coping with uncertainties: challenges for decision makers in healthcare. Journal of Facilities Management. doi:10.1108/jfm-06-2022-0067

Birge, J. R., & Louveaux, F. (1997). Two-Stage Linear Recourse Problems. Introduction to Stochastic Programming, 155-197.

Boateng, W. (2007). Health care decision-makers and knowledge management in the context of a regionalized health care system. University of Saskatchewan,

Boeije, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. Quality & Quantity, 36(4), 391-409. doi:Doi 10.1023/A:1020909529486

Cardoso, T., Oliveira, M. D., Barbosa-Póvoa, A., & Nickel, S. (2015). An integrated approach for planning a long-term care network with uncertainty, strategic policy and equity considerations. European Journal of Operational Research, 247(1), 321-334. doi:https://doi.org/10.1016/j.ejor.2015.05.074

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: synthesis and future directions. Ecology and society, 19(3).

Chapin, F. S., Carpenter, S. R., Kofinas, G. P., Folke, C., Abel, N., Clark, W. C., . . . Young, O. R. (2010). Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in ecology & evolution, 25(4),

241-249.

Dietz, T., Ostrom, E., & Stern, P. C. (2003). The struggle to govern the commons. science, 302(5652), 19071912.

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. Ecology and society, 21(3).

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. Annu. Rev. Environ. Resour., 30, 441-473.

Franken-Champlin, C. (2019). Contextualizing Planning Support (Systems). (PhD). University of Twente, Enschede.

Haasnoot, M., Warren, A., & Kwakkel, J. H. (2019). Dynamic Adaptive Policy Pathways (DAPP). In V. A. W. J.

Marchau, W. E. Walker, P. J. T. M. Bloemen, & S. W. Popper (Eds.), Decision Making under Deep

Uncertainty: From Theory to Practice (pp. 71-92). Cham: Springer International Publishing.

Hadjisotiriou, S., Marchau, V., Walker, W., & Rikkert, M. O. (2023). Decision making under deep uncertainty for pandemic policy planning. Health Policy, 133, 104831. doi:10.1016/j.healthpol.2023.104831

Handley, M. A., Lyles, C. R., McCulloch, C., & Cattamanchi, A. (2018). Selecting and improving quasi

experimental designs in effectiveness and implementation research. Annual review of public health, 39, 525.

Harrison, J. S., & Thompson, S. (2014). Strategic management of healthcare organizations: A stakeholder management approach: Business Expert Press.

Hölscher, K. (2019). Transforming urban-climate governance. (PhD). Erasmus University Rotterdam, Rotterdam.

Hölscher, K. (2020). Transforming Urban (Climate) Governance: What Do We Learn from Pro-actively Experimenting Cities? In K. Hölscher & N. Frantzeskaki (Eds.), Transformative Climate Governance: A Capacities Perspective to Systematise, Evaluate and Guide Climate Action (pp. 241-281). Cham: Springer International Publishing.

Hölscher, K., Frantzeskaki, N., & Loorbach, D. (2019). Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands. Regional Environmental Change, 19(3), 791-805. doi:10.1007/s10113-018-1329-3

Hölscher, K., Frantzeskaki, N., & Loorbach, D. (2020). Transforming Urban Water Governance in Rotterdam, the Netherlands. In K. Hölscher & N. Frantzeskaki (Eds.), Transformative Climate Governance: A Capacities

Perspective to Systematise, Evaluate and Guide Climate Action (pp. 163-204). Cham: Springer International Publishing.

Hölscher, K., Frantzeskaki, N., McPhearson, T., & Loorbach, D. (2020). Capacities for Transformative Climate Governance in New York City. In K. Hölscher & N. Frantzeskaki (Eds.), Transformative Climate Governance: A Capacities Perspective to Systematise, Evaluate and Guide Climate Action (pp. 205-240). Cham: Springer International Publishing.

Hornung, J., & Bandelow, N. C. (2022). Short-term health policy responses to crisis and uncertainty. Journal of Social Policy, 51(2), 365-384.

Iflaifel, M., Lim, R. H., Ryan, K., & Crowley, C. (2020). Resilient health care: a systematic review of conceptualisations, study methods and factors that develop resilience. BMC health services research, 20, 1-21.

Kersten, M. (2024). Making knowledge work. (PhD). Tilburg University, Tilburg.

Kersten, M., Taminiau, E., Schuurman, M., Weggeman, M., & Embregts, P. (2018). How to improve sharing and application of knowledge in care and support for people with intellectual disabilities? A systematic review. Journal of Intellectual Disability Research, 62(6), 496-520.

Kraft, S., Caplan, W., Trowbridge, E., Davis, S., Berkson, S., Kamnetz, S., & Pandhi, N. (2017). Building the learning health system: Describing an organizational infrastructure to support continuous learning. Learning Health Systems, 1(4), e10034. doi:https://doi.org/10.1002/lrh2.10034

Lempert, R. J., Groves, D. G., Popper, S. W., & Steve C. Bankes. (2006). A General, Analytic Method for Generating Robust Strategies and Narrative Scenarios. Management Science, 52, 514-528. doi:https://doi.org/10.1287/mnsc.1050.0472

Mackintosh, N., & Armstrong, N. (2020). Understanding and managing uncertainty in health care: revisiting and advancing sociological contributions. Sociology of Health & Illness, 42, 1-20.

Maillet, L., Lamarche, P., Roy, B., & Lemire, M. (2015). At the heart of adapting healthcare organizations. Emergence: Complexity & Organization, 17(2).

Maki, O., Alshaikhli, M., Gunduz, M., Naji, K. K., & Abdulwahed, M. (2022). Development of digitalization road map for healthcare facility management. IEEE Access, 10, 14450-14462.

Marchau, V. A. W. J., Walker, W. E., Bloemen, P. J. T. M., & Popper, S. W. (2019). Decision Making under Deep Uncertainty from Theory to Practice. Cham, Switzerland: Springer.

Miles, M. B., & Huberman, M. (1994). Qualitative data analysis : an expanded sourcebook (2nd ed.). Thousand Oaks, CA: Sage.

Molenaar, A., Hölscher, K., Loorbach, D., & Verlinde, J. (2021). Making the Transition: Transformative

Governance Capacities for a Resilient Rotterdam. In R. de Graaf-van Dinther (Ed.), Climate Resilient Urban Areas: Governance, design and development in coastal delta cities (pp. 175-190). Cham: Springer International Publishing.

Nunes-Vaz, R., Paul Arbon, Malinda Steenkamp. (2019). Imperatives for health sector decision-support modelling. International Journal of Disaster Risk Reduction, 2212-4209.

O'Mara, M. A. (1999). Strategy and place. New York: The Free Press.

Ogden, J., Morrison, K., & Hardee, K. (2014). Social capital to strengthen health policy and health systems.

Health Policy and Planning, 29(8), 1075-1085. doi:10.1093/heapol/czt087

Pereno, A., & Eriksson, D. (2020). A multi-stakeholder perspective on sustainable healthcare: From 2030 onwards. Futures, 122, 102605. doi:https://doi.org/10.1016/j.futures.2020.102605

Rafiee, M., & Kianfar, F. (2011). A scenario tree approach to multi-period project selection problem using real-option valuation method. The International Journal of Advanced Manufacturing Technology, 56(1), 411-420. doi:10.1007/s00170-011-3177-x

Scholte, M., Marchau, V. A. W. J., Kwakkel, J. H., Klijn, C. J. M., Rovers, M. M., & Grutters, J. P. C. (2023). Dealing With Uncertainty in Early Health Technology Assessment: An Exploration of Methods for Decision Making Under Deep Uncertainty. Value in Health, 26(5), 694-703. doi:https://doi.org/10.1016/j.jval.2022.08.012

Snell, S. A., & Morris, S. S. (2014). Building dynamic capabilities around organizational learning challenges. Journal of Organizational Effectiveness: People and Performance, 1(3), 214-239. doi:10.1108/JOEPP-072014-0033

Sujan, M. A., Habli, I., Kelly, T. P., Gühnemann, A., Pozzi, S., & Johnson, C. W. (2017). How can health care organisations make and justify decisions about risk reduction? Lessons from a cross-industry review and a health care stakeholder consensus development process. Reliability Engineering & System Safety, 161, 111. doi:https://doi.org/10.1016/j.ress.2017.01.001

Torabi, E., Dedekorkut-Howes, A., & Howes, M. (2018). Adapting or maladapting: Building resilience to climate-related disasters in coastal cities. Cities, 72, 295-309. doi:https://doi.org/10.1016/j.cities.2017.09.008

van der Voordt, T. J. (2016). Adding value by health care real estate: parameters, priorities, and interventions. Journal of Corporate Real Estate, 18(2), 145-159.

Van Reedt Dortland, M., Voordijk, H., & Dewulf, G. (2014). Making sense of future uncertainties using real options and scenario planning. Futures, 55, 15-31. doi:https://doi.org/10.1016/j.futures.2013.12.004

Wickramasinghe, N. (2008). Building a learning healthcare organisation by fostering organisational learning through a process centric view of knowledge management. International Journal of Innovation andLearning, 5(2), 201-216.

Zwart, J. v. d. (2014). Building for a better hospital, Value-adding management & design. (PhD). Delft University of Technology, Delft

6 Indicated health & smart health: **Conference paper**

VR-based Body Tracking for Homecare Training

Maximilian Neidhardt*, Sarah Latus, Lennart Maack, Stefan Gerlach, Felix von Brackel, Björn Busse, Alexander Schlaefer

[1] Institute of Medical Technology and Intelligent Systems, Hamburg University of Technology, Germany

[2] Department of Osteology and Biomechanics, University Medical Center Hamburg-Eppendorf, Germany

*Corresponding author: Maximilian Neidhardt

Abstract: Training aids in maintaining and enhancing sufficient muscle function, body control, and coordination, crucial for reducing the risk of fracture incidents resulting from falls, particularly among the elderly or individuals recovering from injury. Virtual reality training presents a cost-effective and personalized approach. We introduce an application for the HoloLens2 aimed at facilitating musculoskeletal training for elderly and impaired individuals, enabling autonomous training and automated progress evaluation. We developed a virtual downhill skiing scenario controlled by body movement to promote balance and body control. By adjusting the parameters of the ski slope, we can customize the training intensity for individual users. In our study, we assess whether the movement data captured solely by the HoloLens2 is adequate for controlling and predicting body movement and joint angles during musculoskeletal training We tracked the movements of 8 healthy volunteers using external tracking cameras and monitored a set of body and joint angles during training sessions. We train a linear regression and support vector machine model to predict the body movement based on the internal recorded head position by the HoloLens2. None of the participants reported motion sickness effects, and all were able to swiftly interact and control their movement during skiing.

Keywords: VirtualReality, PatientTraining, Body Tracking

1. Introduction

Demographic changes present one major challenge for modern medical care (Whitty, 2020). The number of people in need of care is rising while the number of professional caregivers is decreasing. Preventative physical therapy is one approach to maintain the independence of patients and reduce future care efforts. In general, moderate physical activity yields numerous health advantages, especially among older individuals (Vogel, 2009) and those recovering from surgery or injury (Devine, 2009). Reducing the risk of falls through physical and coordination training is an important milestone in preventive home care (Montero-Odasso, 2022). Balance exercises, particularly those excluding walking, have shown efficacy in preventing falls among older adults (Sherrington, 2008) and in training of the musculoskeletal apparatus. Personalized training is essential for older and recovering patients due to variations in their range of motion. However, in the context of an aging society, the number of professional therapists is limited for such training and the willingness to repeat the exercise without guidance can be minimal. Particularly in rural regions, telemedicine emerges as a solution to address the disparity in physician-to-patient ratios and long distances to the nearest medical facilities (Chan, 2021). The accessibility of telemedicine through virtual reality (VR) or augmented reality (AR) has expanded with the commercial availability of VR and AR glasses, a factor often overlooked in head-mounted device setups (Zahabi, 2020). We propose leveraging the HoloLens2 (Microsoft, USA) for cost-effective, supervised physical training tailored to elderly and impaired patients. VR, when combined with traditional physical training, offers significant benefits such as the possibility of independent repetition of exercises (Schoene, 2013) (Mirelman, 2011) (Vovk, 2018).

In this study, we implement a virtual downhill skiing exercise on the HoloLens2 to enable physical training. We designed the exercise with a virtual player mimicking the movements controlled by the patient's head gestures captured in the HoloLens2, making the setup suitable for home-based training without the need for external tracking devices. In particular, we aim to investigate methods to predict body movements solely based on the head motion captured by the HoloLens2. These body movement analyses act as a basis for a patient-specific adaptation of training scenarios and intensity. We calibrate the virtual player's control based on the user's range of motion. Our aim is to enable a user-tailored training program to encourage specific joint movements.

Our experimental study explores the feasibility of predicting specific body movements, such as joint angles, and a complete body model consisting of 32 individual body nodes. For training our methods we track the movement during the experiments with two depth-resolved tracking cameras. Correlation analysis is conducted using data from 8 healthy subjects to assess the accuracy of internal tracking by the HoloLens2. Furthermore, the study demonstrates how parameterizing the downhill skiing scenario allows for personalized training with minimal intervention from caregivers.

2. Methods

We implement a downhill skiing scenario for homecare training. In the following, we present the experimental setup, the data acquisition protocol, and the data processing methods.

2.1 Experimental Setup

The experimental setup is depicted in Figure 1. The setup involves a HoloLens2 (Microsoft, USA) which is a mixed-reality head-mounted-display. The Hololense-2 has internal sensors that can determine the device's position with a sampling rate of 20Hz. Moreover, we independently track the body motion of the player with two external Kinect Azure (Microsoft, USA) cameras. We employ the Microsoft Kinect SDK (2) to engage a body model with 32 individual nodes from the Kinect’s RBG-D data. The two cameras are synced with a trigger cable and the body motion is tracked with 25Hz. The position of each node is defined by using a deep learning algorithm with the depth map and the RGB images from the Kinect camera as input.

We implement a downhill skiing scenario in the Unity game engine. The user is tasked to control an avatar purely through body motion. By driving through virtual blue boxes score points are collected and different tracks can be driven with varying levels of difficulty. In total, we provide three different levels (easy-medium-hard) which are characterized by the amount and steepness of turns. An example of a medium track is depicted in red in Figure 1, right.

The motion of the avatar is controlled through the motion sensed by the HoloLens2 at the user’s head. During training the user is tasked to keep his feet at a steady position to enforce body motion for controlling the avatar. Initially, we perform a user-dependent calibration to estimate the range of motion. Thereby, users who have a limited motion range, e.g., the elderly, can also use the application for training with personalized presets. The speed of the avatar can be changed by flexing the knee. This simulates less wind resistance and thereby a higher speed. A right and left curve is initiated by tilting the upper body to the left or right. During calibration, an initial position is defined which is defined as the zero position.

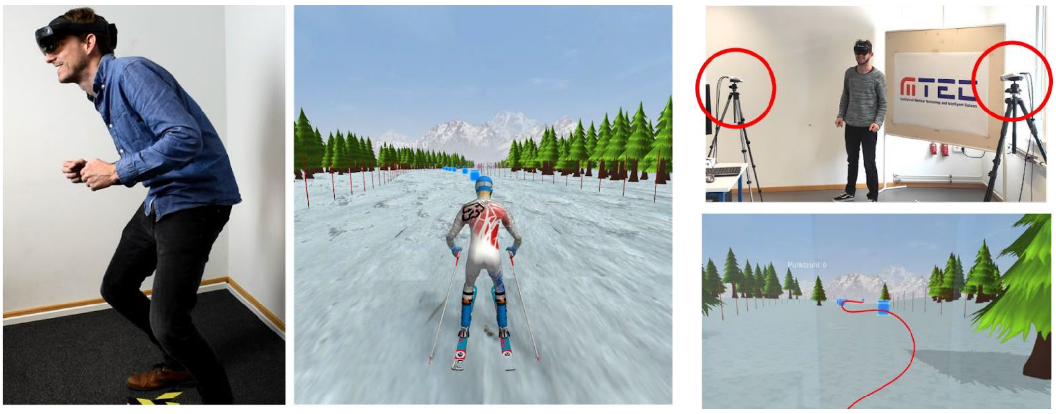


Figure 1. Training setup. We propose a virtual downhill skiing scenario that is played with a mixed reality head-mounted display (HoloLens2), as depicted on the left. The user is tasked to drive a certain track by passing through virtual blue boxes.

2.2 Data Acquisition

We acquire data on 8 volunteers who are tasked to perform 3 different levels of downhill skiing. Each level consists of a start and end point. We define a dataset as one successfully performed level. The average length of a dataset is 89±27sec. We record for each participant two runs of each level. In total, we acquire 48 datasets. The group's average age is 28.8 ± 2.9, with a male-to-female ratio of 70:30. On average, each participant engaged in 3 ± 1 days of physical activity per week and rated themselves as active in sports with 5.5 ± 0.7 points on a scale from 0 to 10. Seventy percent of participants had minimal experience with a HoloLens2, while 30% had moderate experience. Before data acquisition, all participants provided written informed consent.

To remove the bias of the user's position relative to the tracking camera we transform the world coordinate system of the tracking camera into a defined reference system in the body model. The base of the reference system is located at the pelvis node and the axes are defined along the direction of the left hip and the navel. For each recorded frame we derive a transformation matrix.

2.3 Definition of Body Angles

In total, we derive 10 unique body angles from the body model extracted with the Microsoft Kinect SDK. The individual body angles are depicted in Figure 2. We first derive six body angles by estimating the enclosed angle (I-VII) between a set of three designated nodes. These angles are assigned to the lower body motion, e.g., knee flexing. Second, we estimate the angle between two specific body axes (ai) that are defined by two nodes each. These body axes are highlighted as blue lines in Figure 2. We derive the angle between the vectors with $\alpha_{x,y} = \sin^{-1}\frac{|a_x \times a_y|}{|a_x \cdot a_y|}$. These body angles correspond to rotations of specific body parts, e.g. head relative to shoulder.

2.4 Prediction of Body Angles

We analyze deep and machine learning approaches that use the HoloLens2 sensor data as input to estimate either the 10 body angles directly or based on predicting a body model. We either use the body angles or node positions extracted from the Kinect data as ground truth for training.

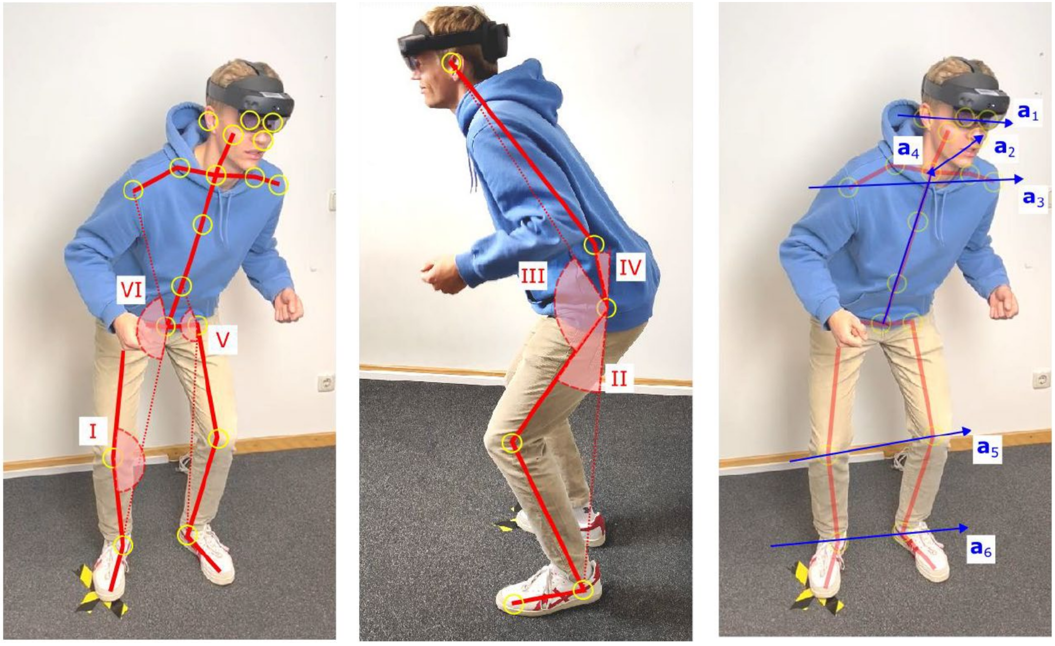


Figure 2. Example of body model with highlighted body nodes (yellow circles), body segments (red solid lines), body angles (I-VII), and body axes (blue vectors, ai). The first body angle (I) is defined from the triangle spanned between the knee, hip, and ankle.

Artificial Neural Network. We train two separate artificial neural networks with a multilayer-perceptron (MLP) architecture to estimate 1) the 10 body angles and 2) the body model consisting of the 3-dimensional position of each node. To estimate possible non-linear relationships between inputs and outputs, we include one hidden layer of size twelve for the estimation of body angles. The neural network architecture for estimating the 3-dimensional position of each node contains two hidden layers of size 24 and 48, respectively.

Linear Regression Model. As a baseline, we employ two linear regression (LR) models. The first model is trained to estimate the 10 body angles directly. The second model predicts the 3-dimensional position of each node. As input, we use the reported spatial position of the HoloLens2 in axis-angle notation.

2.4.1 Training and Evaluation Metrics

We perform a 7 cross-fold validation during training. Thereby, we define in each split recorded data of one user as a test data set and divide the remaining users into validation and training data sets with a 70:30 split. For training the MLP and LR model, we aggregate validation and training data sets. We train all neural networks for 200 epochs. Additionally, we utilize the Adam optimizer and a learning rate of 0.05 and 0.0005 for the task of body angle estimation and 3D node position estimation, respectively. The learning rate was determined after a comprehensive hyperparameter search.

We evaluate the body angle prediction accuracy by calculating the mean absolute error (MAE) in degree relative to the ground truth derived from the Kinect cameras. Further we evaluate the accuracy of predicting the body model by deriving the mean deviation per node position and camera in mm. Finally, we estimate the Pearson Correlation Coefficient between predicted and measured body angles over all users and levels.

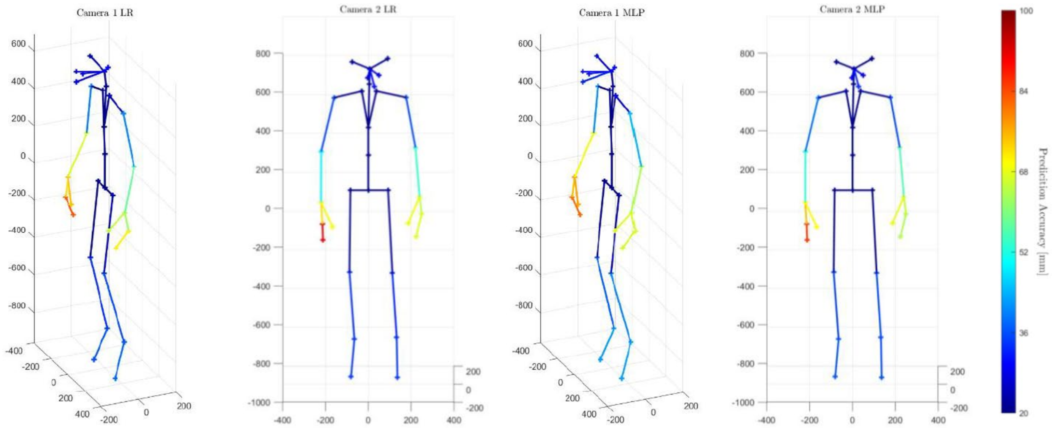


Figure 3. Deviations in node positions derived from the HoloLens2 internal tracking data with a linear regression model.

3. Results and analysis

We summarize the MAEs in predicting the 10 body angles based on the different learning approaches in Table 1. Averaging over all body angles, the MAEs range between 6.09±3.44° and 7.40±4.37° for LR and MLP models, respectively. In general, the body angle estimations from LP models perform slightly better. Tracking the body model, excluding the arm nodes, can be performed with a mean deviation for cameras 1 and 2 of 24.65±18.32mm with the LR model and 25.96±18.95mm with the MLP model. Figure 3 shows the average body model with the estimation errors colorized per body part. The arms can only be predicted with higher deviations of up to 52.88±22.14mm (LR) and 54.10±20.86mm (MLP).

The correlation between predicted and measured body angles during the training over all users and levels is depicted as boxplot in Figure 4. Overall we report mean correlation coefficients of 0.71±0.25 (LR, direct), 0.70±0.25 (LR, body model), 0.67±0.25 (MLP, direct), and 0.65±0.30 (MLP, body model). A higher correlation is given for the LR model in comparison to the MLP. For the majority of body angles, we report a high correlation ranging between 0.7-0.9 (Mukaka, 2012). Only for the body $\alpha_{2,3}$ and $\alpha_{1,3}$ we report a very low correlation. We also calculate correlations separated per level and observe a decrease in correlation from 0.73±0.24 to 0.69±0.21 from level 1 to level 3 using the direct LR model.

Table 1. Mean absolute error (MAE) of predictions in degree (°) for each body angle and model. For the angles I-VI the mean is shown for left and right joint angle predictions. Additionally, the mean motion ranges per body angle over all probands are given.

	I	II	III	IV	V	VI	$\alpha_{2,3}$	$\alpha_{1,3}$	$\alpha_{4,6}$	$\alpha_{3,5}$	Mean
LR model (Bodymodel)	7.49 ±2.93	4.25 ±2.35	8.20 ±4.84	5.89 ±3.15	4.92 ±2.11	6.95 ±4.29	5.71 ±2.72	6.14 ±2.32	4.39 ±2.24	5.78 ±2.36	**6.09 ±3.44**
LR model (Direct)	7.60 ±3.10	4.35 ±2.40	8.21 ±5.06	5.95 ±3.06	5.06 ±2.08	7.05 ±4.58	5.67 ±2.71	6.77 ±3.38	4.41 ±2.36	5.15 ±2.37	**6.15 ±3.60**
MLP model (Bodymodel)	10.07 ±5.89	4.97 ±2.92	9.44 ±5.78	6.50 ±3.21	5.20 ±2.17	7.63 ±4.61	7.97 ±2.80	8.55 ±2.41	5.93 ±3.18	8.31 ±2.86	**7.40 ±4.37**
MLP model (Direct)	9.68 ±4.63	4.69 ±2.22	9.33 ±5.68	6.35 ±2.87	5.01 ±2.01	7.62 ±4.14	5.48 ±2.88	5.69 ±2.54	4.37 ±2.43	5.31 ±2.30	**6.64 ±4.01**
Mean Motion Range	57.54 ±16.91	27.58 ±8.53	60.35 ±13.79	27.25 ±6.50	24.15 ±7.22	39.03 ±11.50	39.40 ±18.15	40.06 ±12.31	39.93 ±13.32	42.68 ±32.11	

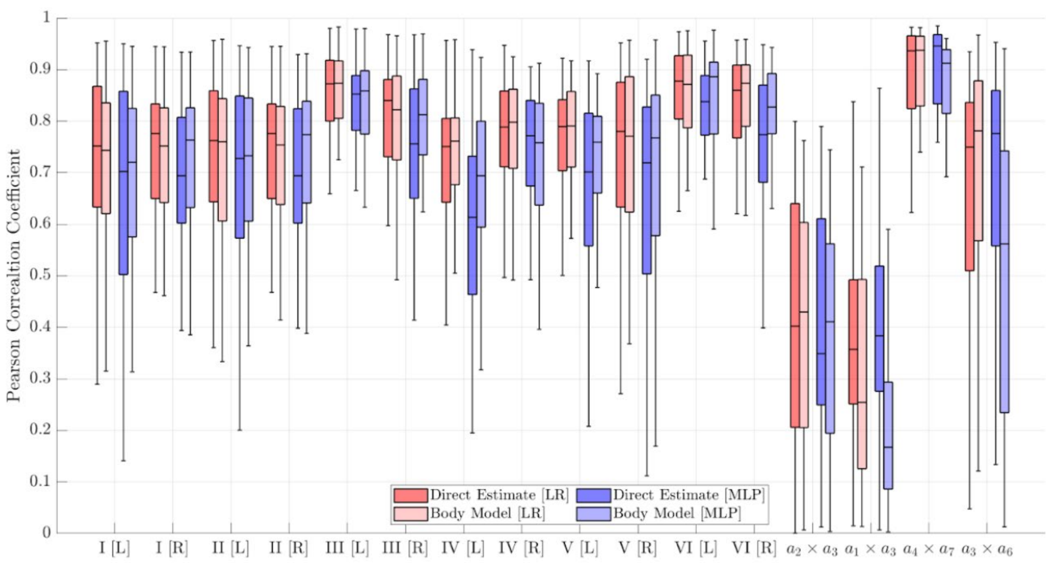


Figure 4. Pearson Correlation Coefficient for body angles over all probands and for different prediction approaches.

4. Discussion and conclusion

Our results demonstrate that we can estimate body angles solely based on the HoloLens2 sensor data with MAEs of up to 10.07±5.89° and 8.55±2.41° for the lower and upper body part, respectively. Considering the LP models, the MAEs do not differ substantially between our direct or our body model prediction approach. However, the direct body angle estimation with MLP performs better than the MLP body model estimation, especially for body angles related to rotations of the upper body parts.

Predictions of the body model show that node positions in the proximity of the head can be estimated fairly accurately, which is related to the input of the model provided by the head-mounted HoloLens2 sensors. In contrast, the position of the arms and hands can only be tracked with low accuracy using the HoloLens2 only.

The correlation analysis demonstrates that the body angles for different experiment levels and probands are similar to each, except for the body angles related to rotations of the upper body parts. The head movement in relation to the shoulder movement seems to be more variable in different probands and levels.

The accuracies of our body angle or body model predictions could be further improved using a higher number of data but also more versatile data sets, e.g., by including probands of different age groups or with different physical limitations. In future studies we will also focus on the user-friendliness and acceptance of our application for the elderly.

In conclusion, we propose that using the HoloLens2 sensor data together with our learning approaches enables a prediction of the probands body motion during training. Especially predicting a body model promises a good basis for providing the user with feedback on the accuracy of movement execution during training. For example, a visual instruction for changing or optimizing the body position based on a current body model would be conceivable.

Acknowledgements

This work was partially funded by Interreg North Sea Region project ACE and the Interdisciplinary Competence Center for Interface Research (ICCIR).

References

Whitty, C. J., MacEwen, C., Goddard, A., Alderson, D., Marshall, M., Calderwood, C., ... & Marx, C. (2020). Rising to the challenge of multimorbidity. *Bmj,* 368.

Vogel, T., Brechat, P. H., Leprêtre, P. M., Kaltenbach, G., Berthel, M., & Lonsdorfer, J. (2009). Health benefits of physical activity in older patients: a review. *International journal of clinical practice, 63*(2), 303-320.

Devine, J. M., & Zafonte, R. D. (2009). Physical exercise and cognitive recovery in acquired brain injury: a review of the literature. *PM&R, 1*(6), 560-575.

Montero-Odasso, M., Van Der Velde, N., Martin, F. C., Petrovic, M., Tan, M. P., Ryg, J., ... & Masud, T. (2022). World guidelines for falls prevention and management for older adults: a global initiative. *Age and ageing, 51(*9), afac205.

Sherrington, C., Whitney, J. C., Lord, S. R., Herbert, R. D., Cumming, R. G., & Close, J. C. (2008). Effective exercise for the prevention of falls: a systematic review and meta-analysis. J*ournal of the American Geriatrics Society, 56*(12), 2234-2243.

Chan, J. K. Y., Klainin-Yobas, P., Chi, Y., Gan, J. K. E., Chow, G., & Wu, X. V. (2021). The effectiveness of e-interventions on fall, neuromuscular functions and quality of life in community-dwelling older adults: a systematic review and meta-analysis. *International journal of nursing studies, 113*, 103784.

Zahabi, M., & Abdul Razak, A. M. (2020). Adaptive virtual reality-based training: a systematic literature review and framework. *Virtual Reality, 24*(4), 725-752.

Schoene, D., Lord, S. R., Delbaere, K., Severino, C., Davies, T. A., & Smith, S. T. (2013). A randomized controlled pilot study of home-based step training in older people using videogame technology. *PloS one, 8*(3), e57734.

Mirelman, A., Maidan, I., Herman, T., Deutsch, J. E., Giladi, N., & Hausdorff, J. M. (2011). Virtual reality for gait training: can it induce motor learning to enhance complex walking and reduce fall risk in patients with Parkinson's disease?. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 66*(2), 234-240.

Vovk, A., Wild, F., Guest, W., & Kuula, T. (2018, April). Simulator sickness in augmented reality training using the Microsoft HoloLens. *In Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1-9).

Mukaka, Mavuto M. "A guide to appropriate use of correlation coefficient in medical research." *Malawi medical journal 24.3* (2012): 69-71.

6 Indicated health & smart health: **Conference paper**

The methodological approach to the AAL4ALL project – From Smart Home to Care Home - the Portuguese pilot experiment

Bruna, Franceschini[1*], Ângela, Pinto[1], Vera, Pinto[1]

[1] Cáritas Diocesana de Coimbra, Portugal

*Corresponding author: Bruna Franceschini (brunafranceschini@caritascoimbra.pt)

Abstract: AAL4ALL - From smart home to care home (A4A) is a project that helps to reshape healthcare by presenting a preventive approach that supports ageing at home. It is aligned with the United Nations' Sustainable Development Goal 3 to ensure access to quality healthcare and promote well-being for all, at all ages, in the face of current demographic changes. A4A technical solution (interoperable room sensor devices) provides indoor climate and smoke alarm monitoring systems while assuring a sense of safety by monitoring anomalies in the older adults' activities of daily living (ADL), and allowing the programming of personalised and prompt care notifications to caregivers based on possible irregularities detected in the older person baseline routine. In this study, the main research question will analyse the extent to which the system supports older people to live autonomously, independently and safely in their own homes. The secondary question will explore whether the system can deduce and communicate to carers indicators of deterioration according to the patterns developed through machine learning algorithms. The study involves a one-year pilot testing phase, which will take place under similar conditions in four countries: Portugal, Switzerland, Romania and Denmark, as well as the collection and analysis of quantitative and qualitative data (through questionnaires and semi-structured interviews). This paper reflects the conceptual framework of the study protocol carried out in Portugal, approved by Regional Health Administration of the Center (Process 49-2023) and does not include data analysis at this stage.

Keywords: AAL4ALL, Smart home, Health&Care, Healthy Ageing, Ageing in Place.

1. Introduction

The rationale behind the A4A approach is based on alarming European data posing that 1 in every 3 older adults (OA) lived alone across Europe and most of them were not qualified to receive healthcare support. According to the same analysis from Eurostat (2017), the countries that will deploy the pilot implementation of the project showed a range between 24 -39% of their older population living alone. In Denmark, 39,5% of 65+ population lived alone; in Romania, the percentage was of 35,6%; in Switzerland, 33,5% and, in Portugal, 24,2%.

The OA who live alone tend to feel insecure if no one knows when they need help, which can have an impact on mental and physical health. Most older adults prefer to continue living in the comfort and familiarity of their own homes, and it is important to develop a supportive system that allows ageing at home and independent living of older people in safe, non-invasive and non-reductive ways (Cheek, 2005).

The A4A solution aims to enable OA to stay independent for longer on their own home by incorporating intelligent systems into their environments, applying non-stigmatizing, affordable and preventive plug-and-play technology earlier to OA that over time can be seamlessly adapted to changing needs. Through the implementation of digital systems for monitoring ADL and movement, the aim is to promote prevention and improve the quality of life of older people. The project seeks to democratise the healthcare system by providing those involved with the tools and resources they need to optimise their approach to care.

2. Methodology

The A4A project will encompass a longitudinal, correlational study, in which the researchers collect and analyse quantitative and qualitative data from the selected sample of participants during the field trial period (12 months). Due to the observational design of the study, there will be no control group. Considering that the pilot project will take place in four different countries (Portugal, Romania, Switzerland and Denmark), the intervention will focus on a participatory and multicentric design, as decisions underlying the field trials process are the results of co-creation and involvement of different partners (business, research and end-users and end-users organisations), and it will be an iterative cycle throughout the project. Beyond that lab test and a demo phase is foreseen before the actual field trial implementation.

The A4A solution comprises an ADLAI Platform (for detection of abnormal activities of daily living (ADLs)), room sensor devices (RSD), which are the core products of the A4A solution and, in some cases, supporting hardware such as motion sensors and front door sensors, for data validation and correlation with the RSD data-driven information, and the Anyware Smartphone application for informal and formal care providers.

The development of the questionnaires and semi-structured interview guide resulted from a collaborative process among partners that started with the identification of aspects that needed to be addressed in the study and monitored throughout the time. The instruments used are conceived as part of the protocol to collect quantitative and qualitative data on the well-being of older people, ADLs deterioration, and issues related to the feeling of safety and the functionalities of A4A technology, during different phases of the trials.

At the beginning of the trial, participants will be presented with a set of sociodemographic questions to gather factual information regarding their profile. This includes information about sex, age, level of education, place of residence, and living conditions. In addition, for the older adults, additional questions about their living environment such as the number of rooms, entry points, frequency of visits and social contacts were enquired to backup technical partners.

To evaluate the well-being of older adults, the primary instrument will be the Well-being of Older People (WOOP) questionnaire (Hackert, 2020). Developed and validated with older populations in the Netherlands, this recent tool offers a comprehensive analysis of the concept of well-being. Additionally, caregivers who have known the older person for a long period, will be invited to answer the Short Form of the Informant Questionnaire on Cognitive Decline in the Elderly (Short IQCODE), the purpose is to assess whether the older adult has behavioural changes (Jorm, 1994; Espírito-Santo, et al., 2010).

To assess participants' performances in conducting their activities of daily living function the questions are partly based on the Barthel Index of Activities of Daily Living (Mahoney & Barthel, 1965). The goal is to understand participants' degree of independence from any help or assistance in relation to the three main ADLs subject of analysis and targeted by the A4A study, which are: ambulating, personal hygiene and toileting. This was a self-assessment report and no direct observation from clinical, or other professionals were made.

To understand the benefits of the A4A system to caregivers, the project adapted the caregivers survey from a community-based program conducted by Lindenmeier, Passmore, Tapps, Gibson, and Liang (2008). The study related to the caregivers' feelings of stress, sense of freedom, and overall satisfaction with the program they were participating in. The A4A adaptation adapted the content and kept the Likert scale original format of the statements and was described as the "Peace of mind-related section". The goal was to assess whether the solution eases life as a career and if proves to be an effective type of digital care. In addition, to measure carer burden among informal caregivers, the 7-item tool, CarerQol-7D (Brouwer et al., 2006) was also administered.

Regarding safety and a sense of security among older adults, the project developed its own set of questions based on the project study hypothesis. Additional aspects related to user acceptance, functionality, perceived usefulness, privacy concerns and general satisfaction will be evaluated using qualitative tools such as semi-structured interviews and direct questions. Users of the Anyware App, i.e., formal and informal caregivers, will assess the usability of the solution by answering the System Usability Scale of Brooke (1996).

Each organisation responsible for the field trials was in charge of doing the translation of materials into local languages and obtaining ethical approvals for implementation, if applicable. The questionnaires can be completed either on paper or digitally using Google Forms, once participants sign the informed consent form voluntarily, proving that they were fully informed about the A4A project and the effects of their participation. Participants who are unable to provide written consent will not be able to participate in the A4A pilot project.

For each of the target groups, the questionnaires to be administered are the following (Figure 1):

Target Group	Older Adults (OA)	Informal Caregivers (Next-of-Kin - NoK)	Formal Caregivers (Professional Care Provider - PCP)
Questionnaires	Sociodemographic Questionnaire ADLS Deterioration (The Barthel Index Adaptation) Well-Being of Older People (WOOP) Safety Related Questions Semi-structured Interview regarding A4A solution, including user acceptance, functionality, and privacy concerns	Sociodemographic Questinnaire The Adult Carer Quality of Life Questionnaire AC-QoL Questionnaire on Cognitive Decline in the Elderly (IQCODE) – Short Form Peace of Mind Related Questions (Adaptation from a community-based programme) System Usability Scale (SUS) Semi-Structured Interview regarding A4A solution	Sociodemographic Questionnaire Peace of Mind Related Questions (Adaptation from a community-based programme) CarerQol-7D System Usability Scale (SUS) Semi-structured Interview regarding A4A solution, including user acceptance, functionality and privacy concerns
Evaluation	Baseline, mid-term and end-line	Baseline and End-line	Baseline and End--line

Figure 1. Field trials evaluation tools

All the ambient sensors will be strategically placed inside the older person home, in different compartments, to monitor their daily routines. The solution does not foresee the use of wearable devices and no health data (blood pressure, heart frequency etc.) will be collected. The A4A solution does not include cameras, video or voice recording.

3. Data collection

For the purposes of this paperwork no results were yet gathered, this is a paper to address the conceptual framework of the A4A project.

The data collection will be carried out at 70 test homes (70 older adults) in the field trials across the 4 end-users countries). The involvement of the older adults in the trials is in dyads - OA plus one caregiver (formal or informal). A key element of this project is the dyad approach based on the user-centred method (Sutcliffe, 2010), in the sense that the project foresees close cooperation and proximity between primary and secondary end-users.

Each pilot must fulfil a specific goal in terms of participant inclusion, with regards to the older adults target group: Ana Aslan International Foundation (ANA), in Romania, must involve 30 participants; Blæksprutten (BLK), in Denmark, must achieve 20 participants; Bonacasa AG (BONA), in Switzerland, must achieve 5 participants; and Caritas Diocesana de Coimbra (CDC), in Portugal, must involve 15 participants.

4. Expected results

The evaluation of the intervention shall be divided into different domains, according to each target group and considering the comparison of results between the different assessment stages.

Concerning the OA, 3 domains will be investigated: overall quality of life, sense of safety, and acceptance of the technology, including in terms of data privacy and intrusiveness. An increase of 20% compared to T0 is expected. This will be based on 3 sub-indicators: changes in the WOOP score, improved peace of mind and increased feeling of safety. A 50% increase in usability compared to T0 is expected, based on 2 sub-indicators: usability of the system and satisfaction with the system. A 30% increase in acceptance is expected, considering drop-out rates, and the percentage of participants willing to keep the devices after the trial.

Regarding the PCP and NoK, the expected outcomes vary from different domains, such as peace of mind and quality of life (≥ 20% for NoKs); acceptance (> 30% of NoK), adoption (> 30% of NoK and PCP willing to pay for the 'commercial' system/package); usability (>= 30% of NoK and PCP rating positive usability); effectiveness (>= 10% Reduction in on-site visits in vain for PCP).

5. Conclusion

The A4A project seeks to contribute to the advancement of existing understanding and alternatives to active and healthy ageing supported by ambient assistant solutions for care. It aims to demonstrate positive impacts on the quality of life of all the groups involved through a careful study protocol developed collaboratively and increase the availability of affordable, reliable, non-intrusive or stigmatising assisted living solutions that operate without cameras, video or voice recording. With this scope, the results will add value to the need for further research in the field (Gadey, 2023).

Acknowledgements

The AAL4All project is co-financed by the European AAL Program and, in Portugal, by the Foundation for Science and Technology (FCT).

References

Brooke, J. (1996). SUS: A quick and dirty usability scale. Usability Evaluation in Industry, 189. 4-7.

Brouwer, W.B.F., van Exel, N.J.A., van Gorp, B., & Redekop, W. K. (2006). The CarerQol instrument: A new instrument to measure care-related quality of life of informal caregivers for use in economic evaluations. Quality of Life Research, 15, 1005–1021. Available at: https://doi.org/10.1007/s11136-005-5994-6

Cheek, P., Nikpour, L., & Nowlin, H. D. (2005). Aging well with smart technology. Nursing Administration Quarterly, 29(4), 329–338. Available at: https://pubmed.ncbi.nlm.nih.gov/16260997/

Eurostat (2017). A look at the lives of elderly today. Available at: https://ec.europa.eu/eurostat/cache/infographs/elderly/index.html

Espírito-Santo, H. A., Matreno, J., Gomes, J., & Reis, R., (2010). Questionário para informantes sobre declínio cognitivo em idosos. Available at: https://dspace.ismt.pt/bitstream/123456789/828/1/IQCODE.pdf

Gadey, N., Pataunia, P., Chan, A., & Ríos Rincón, A. (2023). Technologies for monitoring activities of daily living in older adults: a systematic review. Disability and Rehabilitation: Assistive Technology, 1-10. Available at: https://doi.org/10.1080/17483107.2023.2192245

Hackert, M. Q. N., van Exel, J., & Brouwer, W. B. F. (2020). Well-being of Older People (WOOP): Quantitative validation of a new outcome measure for use in economic evaluations. Social science & medicine, 259, 113109. Available at: https://doi.org/10.1016/j.socscimed.2020.113109

Jorm, A. F. (1994). A short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE): development and cross-validation. Psychological Medicine, 24, 145–153.

Lindenmeier, D., Passmore, T., Tapps, T., Gibson, H., & Liang, Y. (2008). Benefits for caregivers: Case reports distinguishing potential benefits to caregivers of individuals with early stages of Alzheimer's disease participating in designed community-based recreation programs. American Journal of Recreation Therapy, 7(4), 19–26. Available at: https://doi.org/10.5055/ajrt.2008.0024

Mahoney, F. I., & Barthel, D. W. (1965). Functional evaluation: the Barthel Index: a simple index of independence useful in scoring improvement in the rehabilitation of the chronically ill. Maryland state medical journal, 14, 61–65.

Sutcliffe, A., Thew, S., Bruijn, O., Buchan, I., Jarvis, P., McNaught, J., & Procter, R. (2010). User engagement by user-centred design in e-Health. Philosophical transactions. Series A, Mathematical, physical, and engineering sciences, 368, 4209 - 4224. Available at: https://www.researchgate.net/publication/45461280_User_engagement_by_user-centred_design_in_e-Health

6 Indicated health & smart health: **Abstract livinglab DEEL**

Building Resilience
Developing a decision-making model for pandemic preparedness in long-term care

Masi Mohammadi[1,2], Olivia Guerra-Santin[1], Norman Egter van Wissekerke[3], Menno Hinkema[3] , Britt van der Drift[3]

[1] Smart Architectural Technologies, Eindhoven University of Technology, The Netherlands

[2] Research Group Architecture in Health, HAN University of Applied Sciences, The Netherlands

[3] TNO research institute, The Netherlands

Corresponding author: Masi Mohammadi (masi.mohammadi@han.nl)

Abstract: Effective management of health crises demands holistic decision-making models (DDMs) that ensure the safety and well-being of long-term care facility residents amid airborne pandemics. This study, part of the Pandemic Preparedness and Ventilation Program (P3Venti), aims to develop a DDM that provides actionable guidance for policymakers and care professionals.

In this exploratory stage, alongside conducting a thorough literature review on existing DDMs, the research is analysing sensor data, architectural assessments, and observational research from eight healthcare facilities, complemented by stakeholder interviews with their care facilities managers, team leaders, site managers and carers.

The aim is to understand the complex daily interactions and activity levels within care environments and determine how factors such as organizational policies, building design and management influence infection control and the quality of social interactions. From the literature, key factors have emerged as pivotal to the model's structure: healthcare systems, the interplay of governance and policy adherence, community and selfmanagement resources, human factors and behavioural considerations, clinical and information systems, along with the importance of building design and facilities in infection control.

Qualitative and quantitative methods of data collection were employed. Quantitative data regarding daily contacts within care facilities, number of visitors, proximity between/among people, and indoor environment conditions were measured during a period of 3 to 4 days per care home facility. Qualitative data regarding values and priorities in daily care, experiences within the care facilities with Covid-19 measures defined by experts, type and time of contact between staff, residents and visitors, and the practical processes followed were collected through interviews with the 11 stakeholders of the eight care facilities. A mixed method

methodology is used to analyse the results, answering firstly to the questions: How the use of spaces/interactions, weather conditions, building operation and building characteristics affect the indoor parameters in the living rooms? Can we identify the times of the day when the residents are more exposed? What is the relationship between the values and priorities of staff and organizations, and use of spaces/interactions? How far are the values and priorities of residents considered on daily activities?
The anticipated outcome is a comprehensive model that enhances pandemic preparedness and offers flexibility for application across a spectrum of healthcare facilities, aiming for sustainability and economic viability in healthcare practices.

Keywords: Decision-Making Model, Pandemic Preparedness, Long-Term Care, Mixed-Methods Research, P3Venti

6 Indicated health & smart health: **Abstract keynote**

AI & Healthy living

Milan Petkovic

Eindhoven University of Technology, The Netherlands

Philips Electronics, The Netherlands

Artificial Intelligence (AI) has the potential to revolutionize the way we approach healthy living. This talk will explore the opportunities and challenges presented by the integration of AI into smart living environments. We will discuss the latest developments in the field of AI and their potential applications in promoting healthy lifestyles.

AI-powered health services, such as those developed by Philips, offer a glimpse into the future of healthy living. These services can provide personalized recommendations for oral hygiene and pregnancy, among other things. Smart living environments equipped with AI technology can monitor vital signs and even create a digital twin of a human being.

However, there are also challenges to be addressed. The integration of AI into our daily lives raises questions about data privacy and security. There is also a need for collaboration between academia and industry to ensure that the technology is developed and applied in a responsible and ethical manner.

This talk will also provide an overview of the current state of AI in the context of healthy living, as well as a discussion of the opportunities and challenges that lie ahead. We will also present examples of practical applications, that demonstrate the potential of AI to improve our health and wellbeing.

6 Indicated health & smart health: **Abstract keynote**

The continuation of success of health and care via transforming people's daily life and living context. A plea for a mission driven approach from out of the Netherlands.

Nico van Meeteren[1,2]*, Sandra Uljee[1]

[1] Top Sector Life Sciences & Health (Health~Holland), The Netherlands

[2] Erasmus Medical Center, The Netherlands

*Corresponding author: Nico van Meeteren (Meeteren@health-holland.com)

In the Netherlands we innovate to move prevention and care as much as possible to one's own living environment and applicated as much as possible by the people themselves. Technology can support people at large and at the same time each individual to maintain and improve their health and provide the necessary care. This should be backed up digitally by their informal and, if needed, also by their formal health and care providers.

For this all a combination of social and technological innovation, as well as the cooperation between governments, companies, and knowledge institutions and, last but certainly not least, citizens' initiatives and cooperatives, is crucial.

This twenty-year transformative mission driven approach is substantiated by nationwide programs of amongst others: medical, biotech, build environment and digital companies, from start-ups to global players, that in joint coalition with research institutes and municipalities are bursting with ground-breaking innovations. For the most these innovations are discovered, developed and deployed in locally embedded learning communities where learning, innovation and labor are structurally combined. By doing so innovations are adapted and applied almost immediately in daily practice. It's our collective conviction that this mission driven approach will help the societal and economic success that the Netherlands has had the last 150 years to continue and even be enlarged.

6 Indicated health & smart health: **Abstract workshop**

Impact of eHealth

Sander van de Hoef, Margot Rakers

National eHealth Living Lab (NeLL)

With the rapid advancement of technology, the healthcare landscape is undergoing a profound transformation. Digital innovations, particularly those related to remote patient monitoring, offer unprecedented opportunities to enhance patient care, improve outcomes, and optimize resource utilization. In this workshop, we delve into the significance and added value of digital innovations, particularly in the realm of remote patient monitoring, within the domains of medicine and movement care. Various research projects and eHealth interventions will be showcased as examples, providing insight into their applications and impacts. Attendees will be able to engage in group discussions, bringing together diverse backgrounds to explore the barriers and facilitators in implementation, the required cost-effectiveness, and the involvement of end-users. Throughout the workshop, attendees will gain a comprehensive understanding of the latest developments in digital health, focusing on their practical implications and potential for healthcare delivery.

6 Indicated health & smart health: **Abstract workshop**

Celebrating innovation: remarkable cases of extramuralisation and the power of public-private partnerships

Anne Binnendijk[1*], Twan Kerssens[2], Lilian Beijer[3], Chantal Huisman[4,5]

[1] Taskforce for Applied Research SIA, The Netherlands

[2] Health~Holland Top Sector Life Sciences & Health, The Netherlands

[3] Research group Digital Transformation in Rehabilitation Care, HAN University of Applied Sciences, The Netherlands

[4] Research group Technology for healthcare innovations, HU University of Applied Sciences Utrecht, The Netherlands

[5] Building Physics & Services group, department of the Built Environment, Eindhoven University of Technology, The Netherlands

*Corresponding author: Anne Binnendijk (anne.binnendijk@regieorgaan-sia.nl)

An increase in healthcare costs and –demands is expected due to an ageing population with increasingly complex care needs. This development coincides with a relative decrease in the number of healthcare professionals. Therefore, there is a need for innovative solutions that address these challenges, preferably within the clients' own (home) environment. These innovative solutions play a key role within the Dutch Mission-Driven Innovation Policy, specifically Mission II for Health & Care: By 2030, care will be organized 50% more frequently in individuals' own living environment, together with (the network surrounding) people.

Through funding from the Taskforce for Applied Research SIA (as part of the Dutch Research Council – NWO) and Health~Holland (Top Sector Life Sciences & Health), Dutch universities of applied sciences were enabled to conduct innovative research projects in close collaboration with technological companies and end users (both citizens and professionals) to organize care in the own (home) environment. Nine projects, testing a wide variety of technological innovations and targeting diverse populations, ran between 2021 – 2023. In a follow-up call, two large consortia were formed from a selection of these nine projects and were awarded follow up funding (start in 2024). All of these projects are conducted within Learning Communities. A Learning Community, in this context, consists of different public and private organizations and other partners (non, or less organized parties such as citizens and/or professionals), which together contribute to the collective capacity of (livelong) learning, professional practice and innovation. Based on current experience with Learning Communities, certain questions arise, e.g.: "What value does a Learning Community create for the different participants?" and "How can collaboration in a Learning Community be secured for several years?"

7

Biographies

7 Biographies **scientific board**

Prof.dr.ir. Masi Mohammadi

Conference chair, DEEL

Prof.dr.ir. Masi Mohammadi, is a smart living scientist. She heads two chairs—Smart Architectural Technologies at Eindhoven University of Technology and Architecture in Health at HAN University of Applied Sciences—in the Netherlands. Her research program, Empathic Environments, explores the mechanisms of how socio-technological developments influence our living environment and how these are shaped by architecture. Additionally, she serves as a member and chair on several editorial boards and research networks. She is also the Scientific Director of DEEL: a national joint venture among several universities, housing, and care organizations, focusing on integrated strategies for healthy and inclusive living environments.

7 Biographies **scientific board**

Camilla Evensson, MSc

Research Institutes of Sweden (RISE)

Camilla is the manager of RISE´s focus area Future Health and Care that aims to mobilize diverse stakeholders in society to innovate health and care with technology, collaboration and solutions from a systems´ perspective. She has experience in working with cross-disciplinary partnerships with stakeholders like trade and industry, public sector, civil society and end users. She is leading initiatives with a focus on complex societal challenges such as the demographic development, technology test and implementation. Camilla is the lead manager of the Interreg North Sea region project ACE, she is also part of the executive board in ECTP Built4Life.

7 Biographies **scientific board**

Prof.dr. Marta Fernández

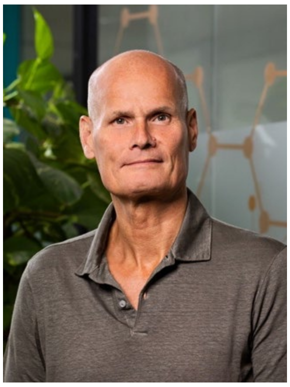
RMIT Europe

Prof.dr. Fernandez was appointed to this role in late 2015. Her career has spanned senior management roles in the UK, including Global Research Leader at international consultancy Arup. She has a strong interest in urban wellbeing, particularly the impact of design and technology for healthy ageing and has been a member of European expert panels for nature-based solutions in cities, energy efficient buildings and healthy buildings. In 2021, She Fernandez was appointed an RMIT Vice-Chancellor's Innovation Professor. She has held honorary appointments at University College London and Imperial College Business School and is member of the Executive Board and Steering Committee of the European Construction Technology Platform, the Triple Helix Association and is a Non-executive Director of Thomas Telford Ltd in the UK. Prof Fernandez has a doctorate degree in carbon sequestration from University College London and is a Fellow of the Royal Society of the Arts and the Institution of Engineering and Technology in the UK.

7 Biographies **scientific board**

Prof.dr. Nico van Meeteren

Health~Holland



Van Meeteren earned his PhD as a Neuroscientist from the Rudolf Magnus Institute for Neurosciences of the Utrecht University in 1994. In 2008 he became Director of Innovation “Healthy for Live” at TNO, with board memberships of amongst others the National Platform Sports and Physical Activity, Body@Work, the Center for Care Technology Research, etcetera. He was also Professor at Maastricht University. At present, from 2015 on, he fulfills his main role as Executive Director and Secretary General of the Top Sector Life Sciences & Health (LSH), known under the name Health~Holland. Furthermore, Van Meeteren is Professor of Perioperative Health at Erasmus Medical Center. From out of both these appointments he holds several governance positions, like that of the national societal theme “Health and Care” of the Mission driven policy of the Ditch Cabinet, Health Research Infrastructure, Regenerative Medicine Cross Borders, Medical Delta, Fit for surgery, etcetera.

7 Biographies **scientific board**

Prof.dr. Niels Chavannes

National eHealth Living Lab (NeLL)

Prof.dr. Niels H. Chavannes MD, PhD, is a distinguished figure in primary care and eHealth. Graduating from Maastricht University in 1998, he earned his PhD in 2005 with a thesis on COPD management. Noteworthy achievements include his role in setting up innovative healthcare centers and receiving awards for integrated COPD management. He has held positions in China and the Netherlands, focusing on clinical research and teaching. Chavannes has authored numerous peer-reviewed articles and contributed to guideline development in respiratory and primary care. He founded the National eHealth Living Lab and has secured substantial funding for research. He holds editorial positions in prominent medical journals and has served in leadership roles in international healthcare organizations. Currently, he works at Streetdoctor Group in Rotterdam, providing healthcare to the homeless. Chavannes's contributions span diverse areas, including eHealth, medication adherence, and smoking cessation.

7 Biographies **scientific board**

Prof. dr. Tineke Abma

Leyden Academy, LUMC

Since 1 December 2019, Professor Tineke A. Abma is Executive Director of Leyden Academy of Vitality and Ageing. For over twenty-five years, she has been researching themes closely related to ageing, such as patient and citizen participation, long-term care, ethics, and diversity. Taking the perspective of older individuals as a starting point and respecting and valuing the differences between people, is her personal motivation and also a key characteristic in the research and activities of the Leyden Academy. In July 2021, Tineke was appointed Endowed Professor of Participation of Older People at the Leiden University Medical Center (LUMC). She leads research activities aimed at strengthening the position of older people and patients in health care, policy, and scientific research, with special attention for the inclusion of vulnerable persons in society.

7 Biographies **scientific board**

Prof.dr.ir. Gloria Gutman

Simon Fraser University

Gloria Gutman, PhD, developed the Gerontology Research Centre and Department of Gerontology at Simon Fraser University (SFU) and was Director of both from 1982–2005. She is currently a Research Associate and Professor Emeritus at SFU. Dr. Gutman is the author/editor of 23 books, the most recent (with Claire Robson & Jen Marchbank) titled Elder Abuse in the LGBTQ2SA+ community (Springer, 2023). During her career, Dr. Gutman has held a number of high profile roles including two terms as President of the Canadian Association on Gerontology, President of the International Association of Gerontology and Geriatrics, and President of the International Network for Prevention of Elder Abuse. Currently, she is President of the North American chapter of the International Society for Gerontechnology, Vice-President of the International Longevity Centre-Canada, and a member of the Research Management Committee of the Canadian Frailty Network (CFN-NCE).

Biography found at: www.sfu.ca

7 Biographies **keynote speakers**

Dr. Christina Fang Dai

Shanghai Jiao Tong University

Dr. Christina Fand DAI has been actively researching China senior care industry since 2019, focusing particularly on strategic studies. As a research fellow at the Institute of Industry Research at Shanghai Jiao Tong University, Christina has spearheaded over ten academic research and government consulting projects. Her recent publications include three case studies featured in the Report on the Pension and Caregiving Industry of China.

Christina served as the Academic Director of the USC-SJTU Global EMBA program in Shanghai from 2012 to 2018. Additionally, she held the position of senior visiting scholar at the University of New South Wales in Sydney, Australia, from 2010 to 2011.

7 Biographies **keynote speakers**

Prof.dr.ir. David Abbink

TU Delft, FRAIM

Prof.dr.ir. David A. Abbink is a full Professor in Human-Robot Interaction, 2 days at Mechanical Engineering, and 2 days at Industrial Design, both at Delft University of Technology. David is a VENI (2010) and VIDI (2015) laureate, and was funded by Nissan, Renault, Boeing.

He leads the transdisciplinary research and innovation center FRAIM, that aims to shape the future of physical work, with and for workers. This entails knowledge integration between workers and a consortium of 35 engineers, designers, psychologists and organizational scholars. The center has received funding from Schiphol, KLM, and Erasmus Medical Centre for work in baggage handling, repair and maintenance work and nursing.

7 Biographies **keynote speakers**

Dr. Evdokimos Konstantinidis

European Network of Living Labs (ENoLL)

Dr. Evdokimos I. Konstantinidis is the Chairperson of the European Network of Living Labs (ENoLL) with more than 170 members worldwide, coordinator of the Health and Wellbeing Living Labs Working Group and postdoc researcher at the Medical Physics and Digital Innovation Lab, Aristotle University of Thessaloniki. He coordinated the Research Infrastructure H2020 project, VITALISE – aiming to harmonize the procedures of Health Living Labs. He is currently the coordinator of the RAISE Horizon Europe funded project on services for the European Open Science Cloud and the Horizon Europe project Engaging the Value Of Living Labs to Innovate Care And Regulatory Environments as a response to the call for experimentation frameworks.

7 Biographies **keynote speakers**

Prof. Ian Spero

Agile Ageing

Honorary Professor, UCL Bartlett School of Architecture and Founder, Agile Ageing Alliance (AAA), a campaigning social business, advocating for a future of inclusive, multigenerational neighbourhoods, designed to boost health and well-being, leading to a reduction in the financial burden on Citizens and State.

7 Biographies **keynote speakers**

Prof.dr. Luis Salvador-Carulla

Australian National University

Luis Salvador-Carulla is Professor of Mental Health and Deputy Director of the Health Research Institute at the University of Canberra. Formerly he headed the Centre for Mental Health Research at ANU and the Mental Health Policy Unit at the University of Sydney. He is specialized in decision support tools for analyzing complex health systems and policy, focusing on mental health, aging, disability, and intellectual developmental disorders. He advised governments of Catalonia and Andalucia, Spanish Ministry of Health, European Commission, and WHO and coordinated the EC projects eDESDE-LTC, Refinement, and PECUNIA, as well as the Integrated Atlas of Mental Health Project, mapping services in 30+ health areas worldwide. He received several awards including the Leon Eisenberg Award from Harvard Medical School (2012), the Tom Trauer Evaluation and Research Award (2022), the Research Impact Award and the Research Excellence Award from the University of Canberra (2023), and the Malaspina Award (2023).

7 Biographies **keynote speakers**

Prof.dr. Milan Petkovic

Philips

Prof.dr. Milan Petković is the head of the Data Science department in Philips which conducts innovation projects for Philips in the domain of machine learning, computer vision, digital signal processing, and secure data management. He is also a part-time full professor at the Eindhoven University of Technology, contributing to the Data Science Center. Among his research interests are data science, big data analytics, and information security and privacy. Prof. Petković serves as the Vice President of the Big Data Value Association (private part of the Big data cPPP) and in boards of directors of several associations and alliances. Prof. Petković is very active in the EU and Dutch national collaborative projects. He has led several big FP7 and Dutch national projects (e.g. collaboration with Australia – AU2EU) and participated in many. He advises the EC by participating in several Advisory Groups for research programs and is part of several editorial boards for data analytics journals. He has published over 50 journal and conference papers as well as several books including a book on Security, Privacy and Trust in Modern Data Management.

This volume presents the collected proceedings of the 1st International Scientific Conference on Smart Healthy Environments: Exploring Healthy Living through the Living Lab Realm, held in Maastricht, the Netherlands, from May 14 to 16, 2024.
It showcases pioneering research and innovations in smart living solutions that improve overall health and well-being.

Editors: Masi Mohammadi, Leonie van Buuren, and Moniek van Loon

For further information about this publication or upcoming events,
please visit www.SHEworldconference.com and www.deelacademy.com

ISBN: 978-90-386-6054-7

Published by Eindhoven University of Technology, 2024