Into the wild

The what, how, and why of using virtual natural environments in residential care facilities

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Rikard Lundstedt Uppsäll

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Title and subtitle: Into the wild – The what, how, and why of using virtual natural environments in residential care facilities

Abstract: Lately, interest has increased in using Virtual Reality (VR) in residential care facilities to increase accessibility to nature experiences. It is widely acknowledged that nature benefits health, and various theories exist regarding its restorative effects. Studies of virtual natural environments often start from predetermined mediating mechanisms and health outcomes. However, virtual nature is fundamentally different from real nature, and people will form different expectations and reactions. Furthermore, by assuming predetermined outcomes and mechanisms, we, as researchers, decide for older adults what and how their virtual natural environments should be, and why they should use them. But we cannot design virtual natural environments with inherent meanings; users will create their own meanings and purposes. Therefore, this thesis took a step back and assumed an inductive approach to explore open-ended possibilities for virtual natural environments. To do this, we invited older adults to test and help design virtual natural environments in our labs, and to use and react to them in residential care facilities. Thus, we aimed to explore what meanings older adults make of virtual natural environments, what factors influence such meaning making, and how virtual natural environments can be meaningful at residential care facilities.

In this thesis, we have reviewed the past use of VR in health and care settings and examined the applicability of virtual nature as a complement to real nature contact. In our VR lab, we have engaged older adults to help design a virtual natural environment through a cyclic process, exploring their preferences and ideas for virtual natural environments and how these can be implemented in a prototype. We have also examined the endocrine effects of an interactive virtual natural environment on older adults in the context of an induced social stress response. Finally, in the wild, across two studies at residential care facilities, we have tested different virtual natural environments and VR devices with residents to explore what meanings they make of virtual natural environments, and how their long-term use at residential care facilities can become a meaningful activity.

This thesis found that older adults in residential care facilities can find virtual natural environments meaningful as a source of stimulation, positive emotions, mood improvement, opportunities for reminiscing and reflection, distraction from challenges, empowerment, and relation building. Further, this thesis found several principles for virtual natural environments for older adults such as realness, interactivity, relatedness and individualised adaptation. We also found that virtual natural environments may support a person-centred approach in residential care facilities if experienced in the context of engaged participation with other actors (e.g., the one who provides VR and guides the user). This process involves VR as a catalyst for relation building through the sharing of memories and emotions, and the co-shaping of virtual environments in relation to the resident's lived reality. Thus, virtual natural environments should not be considered a one-size-fits-all turn-key solution, but require engagement and individualised adaptation.

Key words: Virtual reality, natural environment, older adults, residential care facility, human-centred

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“Happiness only real when shared.”

– Alexander Supertramp, 1992

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Abstract

Lately, interest has increased in using Virtual Reality (VR) in residential care facilities to increase accessibility to nature experiences. It is widely acknowledged that nature benefits health, and various theories exist regarding its restorative effects. Studies of virtual natural environments often start from predetermined mediating mechanisms and health outcomes. However, virtual nature is fundamentally different from real nature, and people will form different expectations and reactions. Furthermore, by assuming predetermined outcomes and mechanisms, we, as researchers, decide for older adults what and how their virtual natural environments should be, and why they should use them. But we cannot design virtual natural environments with inherent meanings; users will create their own meanings and purposes. Therefore, this thesis took a step back and assumed an inductive approach to explore open-ended possibilities for virtual natural environments. To do this, we invited older adults to test and help design virtual natural environments in our labs, and to use and react to them in residential care facilities. Thus, we aimed to explore what meanings older adults make of virtual natural environments, what factors influence such meaning making, and how virtual natural environments can be meaningful at residential care facilities.

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Svensk sammanfattning

Virtuella naturmiljöer kan ge äldre människor i särskilt boende positiva upplevelser om de får välja och använda dem på det sätt som passar dem. Som virtuell naturmiljö-användare i särskilt boende kan man få känna glädje, bli fascinerad och få en omvälvande upplevelse av hur verklig VR-upplevelsen känns. Man kan få uppleva saker som man inte kunnat annars. Man kan få känslan av att ha blivit förflyttad till en annan plats och glömma för en stund, olika saker som tynger ens sinne och ens situation, som på ett särskilt boende för en del kan involvera en känsla av ensamhet och förlorad känsla av kontroll och identitet. Om virtuella naturmiljöer görs på ett sätt som passar en, kan man kanske få tillfälliga upplevelser av att återfå en viss känsla av kontroll, av att styra och bestämma själv vart man vill gå och vad man vill se och göra. Men man ska aldrig pressa någon att använda VR. Man ska inte anta att det blir positivt för alla om man bara anpassar det tillräckligt.

VR har speciella egenskaper som gör att man inte rakt av kan "virtualisera" natur och förvänta sig att det ska vara samma upplevelse som riktig natur. En sak som är avgörande är att fast VR kan ge en stark illusion av att vara på en annan plats, till exempel i naturen, behåller man samtidigt, i de flesta fall, sin vetskap om att man är kvar i rummet där man satte på sig VR-headsetet. VR för på så sätt med sig förväntningar som skiljer sig från verkligheten.

I arbetet med denna avhandling har jag sökt svar på hur äldre människor tycker att virtuella naturmiljöer ska vara och vad de kan vara bra för. Jag har försökt ta reda på vad som ger virtuella naturmiljöer mening och hur de kan användas på ett meningsfullt sätt av boende på ett särskilt boende. Jag har därför bjudit in äldre människor till vårt VR-labb där jag har designat virtuella naturmiljöer i samarbete med dem. Vi har i flera omgångar utforskat en prototyp tillsammans, och de har kommit med åsikter och idéer på hur det ska vara och vad det ger för värde. Under tiden har jag gjort ändringar och tillägg i prototypen och de har på så sätt fått se hur prototypen utvecklats efter hand baserat på deras idéer och åsikter. Många av de äldre människor vi har träffat vill kunna relatera till den virtuella naturmiljön. De vill känna sig hemma och kunna anknyta till minnen. Det spelar roll för upplevelsen hur verklig och konsekvent den känns och om den känns autentisk eller falsk. Det spelar också roll till vilken grad man kan interagera med miljön på ett naturligt sätt och vilken typ av aktiviteter som erbjuds.

Jag har också med andra forskare tagit med virtuella naturmiljöer till särskilda boenden och testat dem tillsammans med några av de som bor där. I dessa studier såg människors väg till en meningsfull virtuell naturupplevelse väldigt olika ut. Precis som i verkligheten, där människor tycker om olika naturmiljöer och vill göra olika saker i naturen är det samma med virtuell natur. Människor har olika minnen, erfarenheter och egenskaper som gör att virtuella naturmiljöer får olika mening för olika människor. Alla har rätt att själva bestämma vad virtuella naturmiljöer ska

vara för dem och vad de ska använda dem till. Vi har sett hur individer kan använda virtuella naturmiljöer på det sätt som ger dem mening, men de kan behöva hjälp att göra detta. Då kan en person som vet mer om VR behövas. Vi kallar en sådan person för ”VR-guide”. Utbildning kan behövas för de som ska hjälpa. Det handlar inte bara om att kunna tekniken utan även om att kunna anknyta till personen på ett sätt som främjar upplevelsen.

Det kan bli positiva effekter i samspelet mellan användaren och VR-guiden som att en positiv relation med ömsesidig omsorg främjas. Vi har sett att virtuella naturmiljöer, om de är utformade på ett sådant sätt, kan väcka minnen och tankar hos användaren och väcka en lust att dela detta med den som är med och hjälper. Vi tror att om personal på särskilt boende är VR-guider skulle det kunna främja ett personcentrerat arbetssätt då VR-sessionerna kan bidra till relationsbyggande och att personalen får reda på mer om den boendes livsberättelse.

VR-guiden behöver även känna till och kunna hantera risker kring VR. Riktigt verklighetstrogen VR kan å ena sidan främja en positiv omvälvande upplevelse, men kan å andra sidan under vissa förhållanden framkalla negativa känslor som obehag och rädsla. En VR-guide behöver vara uppmärksam, kunna bedöma och tolka personen och situationen och kunna på ett säkert sätt guida personen in till, och ut ur den virtuella världen. Under tiden behöver guiden även stödja personen under sin vistelse i den virtuella världen. Om man har kognitiva och mentala utmaningar i vardagen, kan det vara svårt att skilja på den virtuella och verkliga världen. En VR-guide behöver lära känna individen för att kunna ge rätt stöd för hen.

VR är en simulering av verkligheten och kan därför förenklat vara vilken miljö som helst som man kan tänka sig. Därför kan man inte tänka på VR som något som i sig är positivt. Det beror på vad det är för miljö, hur man kan interagera med den och framför allt vem det är som är i den virtuella miljön och hur den passar.

Virtuella naturmiljöer kan inte i första hand användas i syfte att frigöra tid och resurser på ett särskilt boende utan kräver andra människors engagemang. Dess verkliga potential framträder i utbyte med andra människor som fyller det med mening.

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Appended papers

Paper I

White, M., Yeo, N., Vassiljev, P., Lundstedt, R., Wallergård, M., Albin, M., & Lõhmus, M. (2018). A prescription for "nature" - the potential of using virtual nature in therapeutics. Neuropsychiatric Disease and Treatment, 14, 3001–3013. https://doi.org/10.2147/NDT.S179038

Paper II

Lundstedt, R., Persson, J., Håkansson, C., Frennert, S., & Wallergård, M. (2023). Designing Virtual Natural Environments for Older Adults : Think-Aloud Study. JMIR Human Factors ESSENCE: The e-Science Collaboration, 10. https://doi.org/10.2196/40932

Paper III

Lundstedt, R., Jönsson, P., Lõhmus, M., & Wallergård, M. (2023). Endocrine Effects of an Interactive Virtual Natural Environment on Older Adults. Peer-reviewed short paper presented at the 11th International Conference on Serious Games and Applications for Health (SEGAH), Athens, Greece, 28-30 August 2023.

Paper IV

Lundstedt, R., Håkansson, C., Lõhmus, M., & Wallergård, M. (2021). Designing virtual natural environments for older adults in residential care facilities. Technology & Disability, 33(4), 305–318. https://doi.org/10.3233/TAD-210344

Paper V

Lundstedt, R., Håkansson, C., Hedin, M., & Wallergård, M. (In manuscript). Introducing virtual reality as a meaningful activity in a residential care facility - a direct observation study.

The author's contribution to the appended papers

Paper I: A prescription for "nature" – The potential of using virtual nature in therapeutics

I participated in meetings planning the study and read and commented on the manuscript.

Paper II: Designing virtual natural environments for older adults: Think-Aloud study

I planned the study together with my main supervisor Mattias Wallergård. Together, we designed the study procedure, selected questionnaires and constructed a background questionnaire. I translated one of the questionnaires to Swedish. I developed the initial virtual natural environment prototype and performed all the tests with the participants. I performed in-study analysis of the think-aloud questionnaire data and made in-study changes to the prototype based on design decisions (made in consultation with Mattias) derived from the analysis. I performed the qualitative content analysis in consultation with all the authors. I wrote the paper as all the authors read, commented on and approved the final manuscript.

Paper III: Endocrine effects of an interactive virtual natural environment on older adults

I planned the study together with Mattias Wallergård and co-author Peter Jönsson. Together, we agreed on a study design and selected the questionnaires. I recruited the participants and handled the communication with them. I developed the virtual natural environment prototype and performed all the tests with the participants together with Eva-Maria Ternblad, who aided in collecting ECG data and saliva cortisol while I managed the technology. I wrote the paper with support from all authors who read, commented on, and approved the final manuscript.

Paper IV: Designing virtual natural environments for older adults in residential care facilities

I planned the study procedure together with Mattias Wallergård and Carita Håkansson. Together, we agreed on a study procedure. I developed a virtual natural environment prototype that was used in the study and performed in-study development. I and Mattias facilitated VR sessions with residents and I, Mattias and Carita collected observations and performed an interview with the staff. I

transcribed the audio-recordings of the interview and performed the coding and categorization (qualitative content analysis) of the notes of observations, interview and open-ended questionnaire data. I, Carita and Mattias read the documents, discussed, and revised the codes and categories until we had reached consensus on the analysis. I wrote the paper with support from Mare Lõhmus. All authors read, commented on and approved the final manuscript.

Paper V: Introducing virtual reality as a meaningful activity in a residential care facility - a direct observation study

I participated in the planning and study design together with all the authors. I developed a virtual natural environment prototype that was used during the study. Mattias, Carita, and Maria Hedin facilitated VR sessions with residents and collected observations. All authors participated in the qualitative analysis of the observation data. I wrote the paper with support from Mattias and Carita, who read and commented on the manuscript.

Abbreviations

XR	Extended Reality
HMD	Head-Mounted Display
VNE	Virtual Natural Environment
VR	Virtual Reality

Introduction

I was having a bad day. I was feeling anxious and pessimistic due to some worries that I had let grow to unreasonable proportions in my mind. But I remembered what had worked so many times before, so I raised my head to look at the sky. The sun shone on the clouds bringing all sorts of colours, and I felt a little better. I could not explain why, but it was as if watching the sky was like looking out into the world, and I could imagine its vastness and all its problems and possibilities. It gave me some perspective, and my worries suddenly seemed less significant. I felt like taking a walk, so I headed towards the beach. As I walked, I watched the trees move in the wind against the sky as I passed them by and felt a little better. I could not explain why, but it was as if I was going somewhere, not just literally, but a feeling of prospect came to me – an anticipation of the wonderful adventures that awaited me ahead. Walking set my thoughts in motion. I came to think of how I often use different types of spaces to alter my state of mind, and how movement plays a big role. Movement through space calms me down and drives my thoughts forward. My legs move my head on my shoulders through space, and I turn my head and eyes to take in the environment around me. To be alive is to be in the world. To be in the world is to perceive the world. To perceive the world, I move in the world. The act of moving in the world is an essential part of my life. When I arrived at the beach, I fondly remembered past events, and I felt a little better. I could not explain why, but it was as if sensing the past allowed me to realise that there is a future. I thought to myself that others must feel similar things, but in other ways because they have moved in other worlds.

I create virtual worlds. Such worlds are not real, and the people who visit them know that. Yet they often react as if they are real. They lift their feet to avoid getting wet by a virtual surf. They reach to touch the grass in the virtual meadow, and they bow their heads to avoid the branches of the virtual apple tree. Using tracking technology, users can perceive the virtual world by moving as in the real world, sometimes only by turning their heads and eyes. And sometimes they can move their virtual selves through the world, either through assistance or freely on their own initiative. I wonder how humans can use virtual spaces to alter their state of mind. This vision was the starting point for the research presented in this thesis.

This thesis concerns Virtual Natural Environments (VNEs) for the beneficial use of older adults. Lately, interest in such environments has increased and studies have tested various projected health outcomes and mediating mechanisms. This thesis,

rather than taking a starting point in specific predetermined outcomes and mechanisms (with one exception in Paper III), takes a step back and assumes an inductive approach to discover and explore open-ended possibilities. In this introduction, I provide a background to VNEs for older adults and reason why VNEs are essentially a worthwhile venture. In addition, I examine the current state of research in this area and present the aim of this thesis.

Older adults

People in Europe, live increasingly longer lives. The proportion of older adults in the population is growing. According to Eurostat (Demography of Europe — statistics visualised, 2022), the share of those aged 80 years and over nearly doubled from just over 3% to 6% between 2001 and 2021. When statistics such as these are presented, the language used often frames older adults in terms of future burdens on society, such as "health-economic costs" and the questionable term "old age dependency ratio" which describes the ratio of the number of older adults compared with the number of people of working age. Although such perspectives should not be ignored, I would like to add nuance by emphasising the wealth of experience, wisdom, diversity, and valuable contributions that older adults have and continue to bring to their communities, social networks, and relationships.

First, many older adults continue to work well after 65 years, which is seen as the standard retirement age in Sweden. At 70 years, 13% of women still work and 25% of men (Statistics Sweden, 2022). At 80 years, the corresponding numbers are 5% and 12%. Second, older adults continue to contribute significantly to society even after retirement. Around 80% of 80-89-year-olds exercise their right to vote in elections. Among those aged 70-79 and 80+, about 80% and 70%, respectively, are members of at least one community organisation such as a political party, sports club, cultural society, or retiree organisation. Additionally, 36% and 18% of the respective age groups are board members or help organise activities. Older adults possess rich life experiences and accumulated wisdom that can contribute to younger generations (e.g., recognised by initiatives such as WisdomOfAge (Gherman, et al., 2021)). Many are friends, mentors, mothers, fathers, and grandparents who play enriching roles in their social networks and families. With that said, dignity and respect of others in later life should not depend on one's capacity to contribute. Thus, many older adults enjoy a rich, active, and social life. Three of four of 60-69-year-olds perceive their general health status as good or very good (Statistics Sweden, 2022). For 70-79-year-olds, it is six of ten. However, among 80-plus-year-olds, it is only about half. Indeed, some older adults unfortunately experience compromised health entailing functional limitations due to physical disability, cognitive or mental health conditions (Eurostat, Healthy life years at age 65 by sex, 2022).

Residential care facilities

In Sweden, the 4 § Social Services Act (2001:453) mandates that the municipalities:

> shall strive to ensure that older adults can live independently under safe conditions and have an active and meaningful life in community with others (translated from Swedish).

The 5 § Social Services Act (2001:453) further mandates that municipalities:

> shall strive to ensure that older adults have good housing and, in addition, provide those who need it with support and assistance in the home and other easily accessible services (translated from Swedish).
>
> shall establish special housing forms for service and care for elderly people who need special support (translated from Swedish).

In Sweden, residential care facilities are "special housing". They are usually group residencies placed in connection with common areas such as a kitchen, dining hall, and a lounge where residents can gather, socialise, and participate in activities (Statistics Sweden, 2022). Most apartments are about 30-40 m2 and have their own bathrooms (Sveriges Kommuner och Regioner, 2024). Usually, residents bring their own furniture, pay rent and additional fees for care and meals. It is simultaneously a residence, care facility and workplace. There is staff such as care assistants, nurses, certified nursing assistants, activity coordinators, and housekeeping staff who provide service and care.

The official stance in Sweden is that it is generally better for older adults to receive care in their own homes rather than in a residential care facility (Sveriges Kommuner och Regioner, 2021), and the number of older adults receiving care in special housing compared to at home is decreasing (Socialstyrelsen, 2021). Thus, special housing is primarily designated for people who need 24-hour care. Approximately 67 000 older adults in total, and 20% of 90-plus-year-olds live in special housing (Statistics Sweden, 2022).

Unfortunately, older adults living in residential care often experience loneliness and boredom (Nyqvist, et al., 2017; Panthi, 2022; Österlind, et al., 2016). As an example in Sweden, 24% of those living in special housing reported feeling bothered by loneliness *often*, and 46% answered *from time to time* (Socialstyrelsen, 2022). One's own home provides feelings of security and comfort, and through its familiarity, a sense of identity (Cooney, 2011). The transition to living in a residential care facility with standardised care routines can pose a threat to a person's sense of self and identity (Österlind, et al., 2016). Österlind et al. (2016) interviewed 6 older adults in 4 Swedish special housing facilities. The study revealed that life in the facility involved feelings of loneliness in an unfamiliar place, feelings of not being seen as

a person, and having to subordinate to the routines and norms of the care staff. There was a loss of identity from experiencing the expectations of others to change themselves as a person in order to adapt to standardised relationships and care routines. Österlind et al. (2016) further discovered a lack of meaningful relations and few opportunities to discuss existential matters such as thoughts of life and death. Dwyer et al. (2008) interviewed 12 older adults in Swedish special housing and described how inadequate dialogue with the staff "added to the experience of not being involved in daily life" (Dwyer, et al., 2008, p. 106) and unsatisfactory opportunities to influence their everyday life. On the other hand, the importance of a meaningful relation with the staff becomes apparent in this quote by one of the interviewees from the same study:

> I'm particularly fond of two of them. I think we know each other quite well; they know most things there are to know and they know how I want things to be (Dwyer, et al., 2008, p. 101).

It was important to her that the staff knew her and respected her as the person she experienced herself to be, and her values and lifestyle. However, Dwyer et al. (2008) go on to describe a care culture where "everyday life seems to have been controlled more by staff routines than by residents' needs." Österlind et al. (2016) advocate for a person-centred ethos in older adult care.

Person-centredness

Luckily, person-centredness is an increasingly important concept in healthcare (McCormack & McCance, Introduction, 2017). For example, in 2015, the Swedish Association of Local Authorities and Regions (dnr15/4295) adopted a motion to drive the development towards more person-centred care (Sveriges Kommuner och Regioner, 2018). The National Board of Health and Welfare in Sweden's guidelines (Socialstyrelsen, 2017) prescribe a person-centred approach in care of persons with dementia. A person-centred approach means to see and involve the person, and adapt the care according to their individual needs, preferences, values, and other unique circumstances. Thus, to provide person-centred care, the carers need to know the person. Therefore, it is central that the carers take part in accounts of the person's life, family, habits, roles, values, and important events, provided by the person and/or their next of kin (Wijk & Edvardsson, 2020). Such biographies and narratives help to individualise care and facilitate activities that relate to the resident's experiences in life (Buckley, 2017). Thus, staff in older adult care (e.g., at special housing) should possess an interest in listening, and the person a willingness to share and confide. Unfortunately, there are barriers against implementing a person-centred approach, such as high staff turnover, lack of competence and lack of mandate of management to implement changes (Wijk & Edvardsson, 2020). The

staff and management need knowledge about what a person-centred approach actually entails. There can often be a sense among staff and management that they already apply a person-centred approach, even though such is not the case. Although a person-centred approach has been shown to decrease the workload among the staff, it is often thought that it will be an extra task on top of the work they are already doing (Wijk & Edvardsson, 2020). Moreover, although person-centred care interventions are effective, they often lack a participatory[1] approach, and there are challenges with scalability and post-intervention sustainability in older adult care (Kirvalidze, et al., 2024). In a study with observations and interviews with 24 older adults in 6 residential care facilities, Panthi (2022) concluded that despite person-centred policies, older adults in residential care in New Zealand were lonely and bored. She found that there was a lack of activities that residents found interesting because the activities did not match the residents' abilities and interests. In addition, she found that the majority of the residents' interactions were with the staff, and not with co-residents as they felt their interests and status did not match, or that they were in poor health. Unfortunately, as reported by residents and acknowledged by the staff, they were unable to provide individualised attention to the residents to a satisfactory degree, due to high workloads.

As presented above, older adults have active, engaging and social lives. Upon losses in health status and increasing dependence on others, older adults risk losing such opportunities. According to Lawton and Nahemow's Ecological Model of Aging (Figure 1), one's degree of individual competence (e.g., biological health, sensorimotor functioning, cognitive skill, and ego strength) relates to one's ability to adapt to environmental press (Lawton M. P., 1986). An environment can fail to support a person's needs with maladaptive behaviour and negative affect as a result. This works both ways. Environmental press can be too great or too small, either way forcing the person to adapt in harmful ways as this quote reveals:

> There is not a lot that really gets my mind active working properly you know. We do have television in the room but everybody gets bored watching television all the time… [crying]. Sorry but when I am left in the room doing nothing, I feel lonely all the time (Edward, 75 years) (Panthi, 2022, p. 94).

The participant reported that he became very low and needed medication when he was left in his room with no activity.

[1]Participatory, in this instance, refers to the active involvement of patients and the public (i.e., non-professionals) in the design, evaluation, and implementation of person-centred interventions, with the aim of incorporating their perspectives and needs.

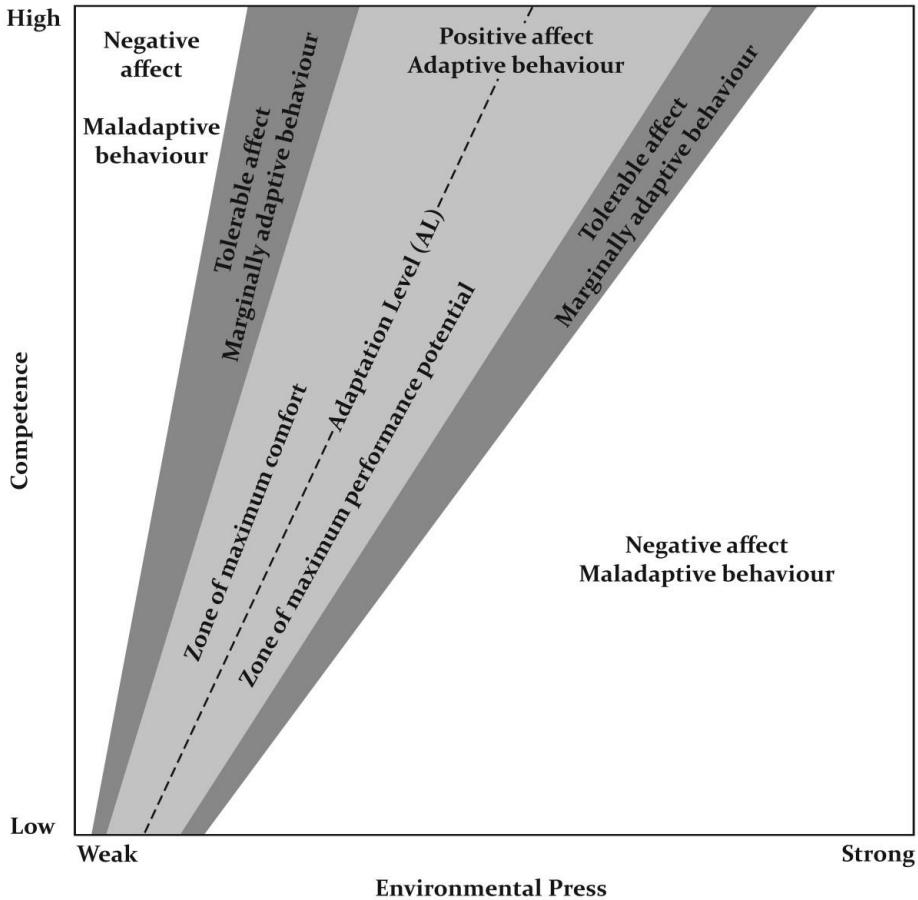

Figure 1. Ecological Model of Aging. Adapted with permission. Source: (Lawton & Nahemow, 1973)

In Europe 2019 (Eurostat, 2021), depressive symptoms were approximately twice as commonly reported by those over 75 (Figure 2). Most commonly, such problems are approached with medications. However, for the older adult population, medications that are used for treating mental and cognitive health problems often have limited effect and negative side effects (Davies & OMahony, 2015). Polypharmacy and inappropriate medication usage is common in the older adult population and often leads to adverse effects (Kucukdagli, et al., 2019; Thorell, et al., 2020), lowering the quality of life for the individual. Furthermore, a rise in pharmaceutical consumption constitutes a risk for environmental wildlife and ecosystems (Arnold, et al., 2014). Therefore, voices have called for non-pharmacological approaches to improve well-being in older adults who have such needs (Woodford & Fisher, 2019).

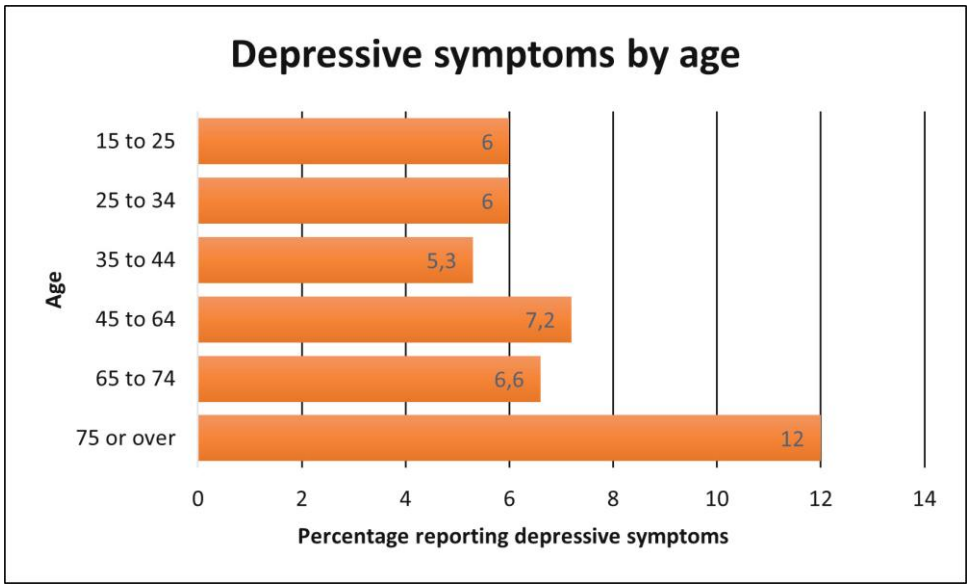

Figure 2. Depressive symptoms by age (Eurostat, 2021).

Although we have sometimes enlisted mobile, healthy older adults as participants (as a next best feasible option, see Paper II), the target group of this thesis is older adults with limited mobility, such as individuals residing in care facilities may have. However, in the following text I will, for practical reasons, occasionally use the term "older adults" to mean this group. It is further important to note that this demographic should not be perceived as a homogenous mass. This thesis refutes sweeping generalisations and stereotypes (e.g., the illnesses an individual may have, does not define them as a person).

Natural environments and virtual reality

There is evidence that it is beneficial for cognitive function, mental health and well-being to spend time in natural environments (Bratman, et al., 2012; Gascon, et al., 2015; Hartig, et al., 2014; Keniger, et al., 2013; McMahan & Estes, 2015; Sandifer, et al., 2015). However, some older adults with poor health have little or no access to do so. According to Lawton and Nahemow's Ecological Model of Aging (Figure 1), the lower the adult's degree of individual competence (e.g., biological health,

sensorimotor functioning, cognitive skill, and ego strength), the lower that person's ability to adapt to environmental press (Lawton M. P., 1986). For many older adults residing in care facilities, their environment is such that the transaction of a visit to a natural environment falls beyond the zone of tolerable affect (e.g., causes discomfort and distress). For example, the physical distance to natural environments from the residence, limited means for transportation, and limited staff resources are some of the environmental factors that may be insurmountable for someone with functional challenges. Indeed, in 2022, 30% of the residents of Swedish care facilities thought opportunities to go outdoors were rather or very bad and only 54% thought they were very or rather good (Socialstyrelsen, 2022). And that is to just go outside; natural areas may not be so close to the facility. In the study by Österlind et al. (2016) (referenced under *Residential care facilities)*, a theme of feeling trapped, physically and existentially, emerged. Iris was dependent on visitors to take her out. Only when her children came to visit did she get a glimpse of life on the outside. The theme also bore an existential feeling of being imprisoned within oneself, relating to standardised relationships and care routines at the facility.

> I think that I feel restricted. I feel that I cannot go where I want and such like. It would be a bit more fun if one could spend time in the fresh air. But instead you have to stay indoors. (Österlind, et al., 2016, p. 5)

It is my firm belief that it is society's responsibility to provide an environment to its citizens' needs. There are ongoing research efforts to map and promote older adults' access to outdoor environments in residential care facilities (Liljegren, et al., 2022). However, in some cases, the task of adapting the environment to a level where the demands are in balance with the individual's ability to adapt may prove insurmountable (i.e., even though other person-centred goals may be met, satisfactory access to real, natural environments may not be possible for some older adults).

At residential care facilities, attempts have been made at indoor nature activities, such as indoor gardening, pictures, moving images and Virtual Reality (VR) depicting natural environments (Yeo, et al., 2019). However, the review by Yeo et al. (2019) did not find enough evidence to recommend indoor nature above other interventions. The review also found that images, movies and VR were less effective than activities involving real plants. However, the VR study examined in the review (Moyle, 2018) utilised a single large screen for displaying the virtual environment which can be regarded a non-immersive[2] type of VR. Likely, most viewers of such a VR setup would maintain their feeling of being present in the residential care

[2] Immersion is an objective property of a VR system that determines its capability to support sensorimotor contingencies. It encompasses properties such as field of view, display resolution, positional audio, haptic feedback, and user body tracking to facilitate accurate responses to perceptual actions, such as bending down to look underneath or reaching out to touch something.

facility, watching a virtual environment that exists somewhere else or "over there" on the screen. However, VR technology such as Head-Mounted Displays (HMDs) featuring user tracking and stereoscopic displays can provide the perceptual illusion of being present inside the virtual environment (Slater, 2018; Makransky, et al., 2019; Shu, et al., 2018; Cummings & Bailenson, 2015).

Attention Restoration Theory (Kaplan, 1995) suggests "being away" as a vital component of a restorative experience. The idea is that the sense of "being away" may contribute to providing relief from an otherwise constant demand for directed attention. Reasonably, for a sense of "being away" to materialise during a virtual nature experience, a sense of being present in the virtual environment is required. Another vital component that Attention Restoration Theory suggests is that the environment should have "extent," which entails that it is perceived as a whole other world. Although I do not use Attention Restoration Theory as a foundation for designing VNEs, I find it interesting that these components align with fundamental capabilities of immersive VR – the ability to provide the illusion of being in a different place, and the illusion that this different place is in fact a real place (Slater, et al., 2022). Through the capabilities of immersive VR, a resident at a care facility may feel as though they have been transported outside into a natural environment upon putting on an HMD featuring a VNE.

Thus, it is reasonable to propose that immersive VNE exposure may work as a complement to real, natural environment exposure for older adults with limitations in mobility. I reject a technological solutionistic narrative (Wyatt, 2023) around VR – society should not rely on VR to solve its accessibility challenges or think that it can be a quick fix for older adults' well-being. However, the prospect of helping someone who has limited access to have more experiences of spending time in nature is reason enough for me to embark on investigating such possibilities.

Virtual natural environments in research

Lately, a few studies involving older adults experiencing VNEs with immersive technology have been conducted with some positive outcomes. Results from these studies include displayed enjoyment and relaxation (Appel, et al., 2021); positive responses, a soothing effect, and evoked memories (Orr, et al., 2021); and improved nature connectedness and positive affect (Chan, et al., 2021). That is all well and good, but among studies, VNEs are very heterogenous in terms of the design and technology used (Nukarinen, et al., 2022). The same goes for the projected value or purpose of VNE use, and the mediating mechanisms which are often derived from non-VR related sources (e.g., Attention Restoration Theory, Stress Reduction Theory and Biophilia Hypothesis). The research area is scattered, and it is difficult to make sense of the *what*, *how* and *why* of VNEs for older adults. It is not surprising

since they are still in their infancy – they are uncharted territory. In their integrative narrative review of restorative VNEs, Nukarinen et al. (2022) constructed a *Multidimensional Model of Restoration* connecting theories and restoration measurements. They found gaps in the restoration types measured and advocated for more holistic measurement. Utilising multidimensional measurements can encompass a broader spectrum of experiences and responses within VNEs, accounting for a greater diversity among participants. However, not enough studies invite older users to help design VNEs or inductively investigate their meaning[3]. Studies often test a certain flavour of VNE with a preconceived way in mind in which they will be beneficial or valuable. But VNEs cannot be designed with inherent meanings; users will find their own. And if users cannot develop intrinsic motivation, they will likely abandon them. Therefore, we should take a few steps back and keep an open mind about what VNEs can be, about their potential meaning, application, acclimatisation, and impact. And instead of imposing our own assumptions about how older adults will use VNEs and what they will mean to them, we should allow the intended users to participate in the exploration of what VNEs should be and what they should be good for.

Peine et al. (2014) warn of a paternalistic stance in the design of gerontechnology (technology for older adults) where older adults have often been described in terms of their medical detriments and seen as passive receivers of technology as remedies for their pre-existing needs; this rather than as active consumers of technology to enhance meaning and identity in life. Furthermore, older adults have often been perceived as technologically illiterate and resistant to adopting new technologies. This is something that often has been seen as only initial and necessary to overcome for their own good. Consequently, paternalistic attitudes have often led designers to presume the authority to study and define older adults' user needs and design technology accordingly. Thus, older adults risk exclusion from the role of being co-creators and the opportunity to explore new possibilities and practices that new technology may bring (Peine, et al., 2014).

Even though I hope that VNEs will ultimately exist that can benefit the well-being of older adults who have such needs, it cannot be the starting point for our studies. Thus, we have not profiled older adults' detriments and constructed well defined sets of needs to solve with our designs. Instead, we have attempted to facilitate processes where older adults' reported experiences, preferences and ideas can propel the design.

This thesis strives to aid the design and research of VNEs for use by older adults by contributing to an understanding of their meanings of VNEs, and how they may

[3] The subjective perception, understanding, and attribution of value, significance and purpose to objects, actions, or concepts (Krippendorff, 2006). Meaning resides within the individual, and not within the object. It is shaped in social interactions and cultural settings, is not fixed but in flux, and is sensitive to the context.

shape and appropriate VNEs into their lived realities. It is my proposal that such an understanding is pivotal to have before considering specific targeted benefits of VNEs or restorative frameworks in a VR context. Further, to design VNEs that older adults will want to use, they must be allowed to appropriate VNEs in ways that make them relevant to their lives and experiences. As consumers of technology, we often have little grasp of why and how the technologies we consume came into being. In our minds, it was formed inside a black box by the hands of experts who know what they are doing. This may contribute to an unrelenting technological determinism (Wyatt, 2023) that sometimes makes us less inclined to question its use and purpose. I aim to resist such determinism, because if we are serious about designing VNEs for older adults, we should reserve the right to keep an open mind about what VNEs can *become in their hands*. Thus can VNEs become something older adults find meaningful and will want to use, rather than something that has simply been *put in their hands*.

Research aim and questions

The overarching aim of this thesis was to discover and explore open-ended possibilities for VNEs for older adults by inviting older participants to test and help design VNEs in a lab environment, and to use and react to VNEs in residential care facilities. Thus, we explored the following research questions:

(1) *What meanings do older adults make of VNEs?*

(2) *What factors influence such meaning making?*

(3) *How can VNEs be used in a meaningful way in residential care facilities?*

Theoretical foundation and methodological considerations

This thesis is about the design of virtual natural environments for the beneficial use by older adult humans. It therefore makes sense to describe it as belonging to the field of *Human-Centred Design of Virtual Environments*. As humans' usage of virtual environments is a form of computer interaction, it draws on Human Computer Interaction theory as well as VR theory and Human-Centred Design. Human Computer Interaction is "the study and practice of the design, implementation, use, and evaluation of interactive computing systems" (SIGCHI, 2018). Throughout Human Computer Interaction history, it has expanded its scope and imported different theories and approaches from other fields. Human Computer Interaction and Human-Centred Design are highly related and overlapping fields. In this chapter, I present and interconnect selected theories of Human Computer Interaction/Human-Centred Design and VR to provide a conception of my theoretical and methodological approach for this thesis.

Human-centredness

In his book *The Semantic Turn*, Krippendorff (2006) describes a turn from technological determinism that is a heritage of the industrial era, towards human-centredness where humans are able to influence the direction of technological development. Krippendorff writes of how humans form their meanings of artefacts in use and in communication with others. He draws on the linguistic turn in philosophy that entails that realities are created using language, that is, humans coordinate their conceptions by using language and thus construct and reconstruct realities. For example, artefacts do not possess objective meanings. By artefacts is meant, besides human made physical objects, concepts such as colour. Concepts are the results of humans forming consensus about that which they perceive. For example, colour does not physically exist in the way it is commonly conceptualised by humans.

As humans coordinate their understanding with others, different meaning arises within boundaries, such as professional discourses. Therefore, artefacts have

different meanings in different contexts. This has big implications for VR. As we shall see under *Immersion and presence* and *An inductive approach*, VR is not a mere simulation of reality. It is a fundamentally different experience with unique properties that have significant impacts on meaning making.

Krippendorff turns away from the perspective of technical rationality in design (i.e., engineering-like problem solving in an established practice), and proposes that users find their own meanings and purposes of new technology and influence the direction of technological development. The designer's role is to "consider possible futures, challenge[] theories and explore new ideas" (Krippendorff, 2006).

User involvement

From Lawton and Nahemow's ecological model of aging (Lawton, 1986) (Figure 1) it becomes evident that for many older adult users, the level of environmental press that can be exerted must be on an extremely narrow band between weak and strong to achieve positive rather than negative affect. According to the model, it depends on the person's "competence" where these boundaries exist, and since this varies a lot among the older adult population it is very likely that what is a good level of environmental press for one user is bad for another. Thus, user involvement is highly important in design with older adults. In their seminal paper, Gould and Lewis (1985) argue that three principles must be followed to produce a useful and easy-to-use computer system:

> Early and continual focus on users and tasks; empirical measurement of usage; and iterative design whereby the system (simulated, prototype, and real) is modified, tested, modified, modified again, tested again, and the cycle is repeated again and again (Gould & Lewis, 1985, p. 300).

I strongly adhere to Gould and Lewis's principles of early and continuous involvement of potential users in the design with hands-on tests, so that the diversity of needs and behaviours of older adult users (in relation to VNEs) may be discovered. However, even though Gould and Lewis's principles focus heavily on user involvement, they are still worded in a slightly technology-centred way in that they assume an existing practice and focus on measurable behaviour goals that should be defined beforehand. Therefore, I have had to adapt these principles to a more human-centred approach. Partly because there is so little knowledge of VNEs for older adults, I do not approach it as an existing practice. I try not to impose new technology on older adults for a particular use because artefacts do not possess inherent meanings (Krippendorff, 2006). In Gould and Lewis's principles I have therefore replaced the measuring of predefined behaviour goals with the gathering of an understanding of how users form their meanings and purposes of their use of

VNEs. Inspired by Krippendorff's (2006) Human-Centred Design, I attempt to introduce novel technology for users to adapt on their own terms, find their own meanings and purposes, and let their process guide the design.

I believe that user involvement should be reflective and dynamic, sensitive to the unique context and development of the situation and should not be thought of as a recipe you can follow that will guarantee good results, or a checkbox you can tick to validate your process as ethical and effective. As Löwgren and Stolterman present (2005, p. 41), a "thoughtful design stance" entails viewing nothing as given or true and the entire situation as a design task: to actively shape and refine the process according to the specific needs and evolution of the project. Unreflected, user involvement can produce negative results as well as positive (Fischer, 2022). Simplified, participation can exist on a scale or "ladder" (Arnstein, 1969) of participant empowerment that ranges from none to full. For example, user involvement can be manipulative, tokenistic, or empowering. If used with ill will, or carelessly, user involvement can even enforce oppressive structures (Guo & Hoe-Lian, 2014). A facilitator of participation must also be attentive to power relations. For instance, a title such as doctor or professor exudes authority and can unknowingly skew participants' contributions towards the researchers' biases. Since power relations are context-sensitive, dynamic, bi-directional and very complex, they cannot be covered by guidelines or checklists. Instead, a reflective approach and readiness, along with an openness to the fact that troublesome power dynamics inevitably occur in ways one cannot expect to foresee, are needed (Lyon, et al., 2010).

Affordances

Affordances is a key concept in Gibson's (1979) theory of visual perception *Ecological Psychology*, which has had a big impact on Human Computer Interaction. The theory holds that seeing and acting are strongly interconnected. Gibson's view of the visual system includes movement of the eyes, head and body. It implicates that perception takes place through action, for example, sideways head movements enable the perception of surfaces behind occluding edges. Affordances are properties in the relationship between the environment and organisms (e.g., humans) that make certain actions possible for certain organisms. For example, stairs afford climbing to an organism whose leg size matches the size of its steps. They are what the environment offers both in terms of possibilities and constraints (e.g., a clear path affords passage while a blocked path affords hindered passage). Gibson meant that noting an affordance is a "direct perception" that does not rely on any internal processing or mental model. The concept of affordances has been adopted into Human Computer Interaction as a way for artefacts to communicate possible actions to their users. There has, however, been some confusion around

whether it makes sense to talk about affordances in relation to screen-based interfaces. Norman (1999) stated that it is not an affordance that you can click on an icon on the screen because you are just as able to click anywhere else on the screen. He also stated that by affordances he meant *perceived* affordances. Real affordances are those that are physically possible; they may or may not be perceived. And perceived affordances are simply those that are perceived, they may or may not be possible[4]. For example, a secret door is a real affordance that is not perceived, while a painted door is a perceived affordance that is not real. He also meant that affordances, real or perceived, do not typically exist in screen-based interfaces.

> Far too often I hear graphic designers claim that they have added an affordance to the screen design when they have done nothing of the sort. Usually they mean that some graphical depiction suggests to the user that a certain action is possible. This is not affordance, either real or perceived. Honest, it isn't. It is a symbolic communication, one that works only if it follows a convention understood by the user. (Norman, 1999, p. 40)

Let us consider the action of dragging a file icon across a tablet screen. The way the screen is constructed allows no way for it to present any properties that would make it perceptually obvious that it can be dragged. The icon does not protrude out or show any signs of separation from the uniform flat surface of the screen. Like most screen-based interfaces, the tablet relies on analogies of real-world actions that have become convention and must be learnt. However, VR is a special case of a screen-based interface. It is my position that VR in fact *relies* on affordances, as we shall see in the following section.

Immersion and presence

Immersion and presence are two concepts that are central to VR theory. Immersion is most often referred to as the objective, technical capabilities of a medium that allow a person to be immersed (e.g., in a virtual environment). Different media can be said to be more immersive than others. Presence stands for the sense of "being there" (e.g., in a virtual environment). It is a subjective phenomenon that is experienced by the user. As an example, a user may get a sense of presence while using an immersive medium. Gibson (1979), Krippendorff (2006), O'Regan and Noë (2001) and many scholars of Human Computer Interaction (Rogers, 2012) hold

[4] However, other interpretations entail that "real affordances" are such that are perceptually obvious and do not require learning (Rogers, 2012), for example, properties in the world matches properties in the organism in a way that an action is possible, as in the hand matches the fruit, which affords picking. Meanwhile, "perceived affordances" are such that are based on learnt conventions and feedback.

that perception takes place through action. In the case of VR, this is demonstrated by how VR works to provide the sense of presence. Slater et al. (2022) describe presence as composed of two dimensions: "place illusion" and "plausibility". Place illusion can occur within the boundaries of an immersive VR system. An immersive VR system works through affording natural sensorimotor contingencies[5]. Such affordances allow a user to perceive the virtual world through actions similar to how one would in the real world (e.g., head movements to look around you or behind objects) (Slater, et al., 2022). In a typical VR system of today, this is made possible through the use of a Head-Mounted Display (HMD) which is a headset with displays that are placed in front of the user's eyes. The HMD is constructed to substantially fill the user's field of view with imagery of a virtual environment and at the same time block out the real world. It also has speakers at each ear to provide the user with audio of the virtual environment. The HMD possesses tracking possibilities that allow the system to update the visual and audial perspective of the virtual environment according to the user's movements. The system usually comes with handheld controllers to allow manipulation of the virtual environment and rudimentary haptic feedback (sense of touch). Place illusion is maintained as long as the user's actions result in the (approximate) expected change in perception. For example, if a user reaches out and touches something they see, in a virtual environment that does not support haptic feedback, they momentarily break place illusion. Based on these premises, I do not count a VR system based on a single monitor or TV screen as an immersive system. This is because even if a user sits close enough that the image fills their entire field of view, which is not very likely, it does not allow the most basic perception-through-action, such as turning one's head, before breaking place illusion. This is because if the user turns their head, they will clearly perceive their presence as in the room where the TV resides, and not in the virtual world that is over there on the TV.

From the presentation above, it should now be clear that VR relies on affordances (as proposed in the previous section) because the key to presence in VR is to afford real-world perception-actions; for example, turning your head rather than pulling a joystick to look around you, or extending your arm rather than using a computer mouse to grab an object.

Plausibility is the illusion that events that the user perceives to happen in the virtual environment are really happening (Slater, et al., 2022). Plausibility relies on the virtual world acknowledging the user, beyond the sensorimotor contingencies previously discussed. For example, a virtual actor smiles at the user or moves out of their way as the user advances towards them. Plausibility also relies on the virtual world's trueness to reality in terms of appearance and behaviour. However, in some

[5] Contingencies are the relationships that link events or actions with their effects (e.g., how something is moved if pushed).

cases, users may accept certain departures from realism as part of how the virtual world works and thus plausibility may be retained.

Even though place illusion breaks momentarily when a system fails to provide the expected perceptual feedback to a user action, it is quickly restored when such conditions cease (Slater, 2009). For example, if the HMD glitches and the image freezes for a moment, the user's sense of being in place cannot be maintained during this moment, unless they happen to close their eyes or stand precisely still as it happens. But as soon as the HMD returns to normal functioning the user is back in place. It may only affect the overall sense of presence if such breaks are frequent. However, with plausibility it is different, because when it has been broken, it cannot easily be restored, as illustrated by this excerpt from a qualitative study of breaks in presence by Garau et al. (2008).

> Once the belief in the [virtual] characters was undermined, participants stopped treating the [virtual] bar as a social environment and began exploring it as if they were alone, uninhibited by the presence of others. (Garau, et al., 2008, p. 304)

It is especially important that the illusions that VR provides are, with certain exceptions (see Paper V), perceptual and not cognitive (Slater, et al., 2022). That means that if users obtain place illusion and plausibility, their immediate reactions to events in VR are as if it is real, but they maintain their awareness that it is not. This is one thing that makes VR fundamentally different from real-world experiences. VR cannot be seen as a mere simulation of the real world. It is a fundamentally different experience that possesses unique possibilities and conventions (Slater, 2009).

An inductive approach

There exist various theories of restoration in natural environments such as Attention Restoration Theory (Kaplan, 1995), Stress Reduction Theory (Ulrich, et al., 1991), and Biophilia Hypothesis (Kellert & Wilson, 1993), and accompanying tools that can be used as a guideline for the design of such restorative environments. Studies involving VNEs have often quoted such theories, putting them to the test and/or basing designs of VNEs on them. However, I have taken a different approach. As previously argued, VR cannot be seen as a mere simulation of the real world. It is a fundamentally different experience that possesses unique possibilities and conventions (Slater, 2009). As VR is essentially different from actual reality, VNE use will form a discourse of its own and meanings of VNEs will be shaped in this discourse. For example, VNEs may be referred to in terms that reflect the properties and characteristics of VR, for instance, realistic, fake, resolution, static, and amazing. Thus, the virtual version of an environment will be inscribed with different

properties than the corresponding real environment. The fundamental consequence of VR cannot easily be escaped. It is at times a mind-boggling experience. A second ago, you were stuck in your wheelchair at the residential care facility, but now you are climbing Mount Everest. Naturally, this fact will affect the experience in a fundamental way.

Moreover, since we are not yet at the technologically advanced level of the Star Trek universe where holodecks exist, VR can so far only provide a limited set of interaction capabilities. This is because with today's technology, it is not feasible to implement every imaginable possible real-world action in VR. As an example, imagine all the aimless random fidgeting that is possible to partake in, like picking a leaf from a tree, tearing it into tiny pieces and rolling them between your hands to form a sort of paste. Designers cannot implement all such random manipulations. They must, necessarily, select a subset of possible actions. And because it is a subset, and users mostly know this, it will work as clues to perceived designer-intentions and thus affect meaning making. For example, as a user discovers that they are able to pick up things, they may start to wonder what they are *supposed to do* with this ability, for instance, "What am I supposed to do with this tree-branch?" In a real natural environment, the excursionist will not "discover" that they are able to pick up things. They are mostly aware of their basic physical capabilities already, and it is probably rare that they ponder what they are supposed to do with pieces of natural debris.

Based on these reasonings, and leaning on Krippendorff (2006) and Slater et al. (2022), I posit that people will form essentially different meanings of VNEs than of real natural environments. Thus, I could not rely on theories of restoration in real natural environments as guidelines for the design of VNEs. Instead, because there is a lack of knowledge of VNEs that does not rely on other sources, I assumed an inductive[6] approach to build knowledge from the bottom up in a VR context.

An analytic perspective

At the centre of my approach is to gather an understanding of what meanings and purposes older adult users make of VNEs. As VNEs at residential care facilities are not an established practice, part of my human-centred approach is to keep an open mind about what VNEs can be, and to attempt to devise a process that is sensitive to discovering *unknown unknowns*, that is, unknown aspects, circumstances, relationships, effects, and other things that we could not have imagined. In addition

[6] As opposed to a deductive approach, which typically takes a starting point in a hypothesis or theoretical framework, an inductive approach attempts to let unprejudiced insights emerge from the data, often through an exploratory process (Creswell & Creswell, 2023).

to Krippendorff (2006), I lean on Suchman (1987), who showed that people often use interactive systems in a different way than what is intended by the designers. She took an analytic perspective from primarily an ethnomethodological position. Ethnomethodology rejects abstract theorising of social reality, and instead holds that social reality is formed through social interaction among individuals (Dourish, 2001). Thus, ethnomethodology is the study of how people form social order through their everyday reasoning about their actions in relation to other's intentions, and thereby form common understandings. Suchman (1987) presented a model of interaction where people organise their actions in the moment according to the situation at hand and in relation to physical and social circumstances rather than according to a preformulated plan, predictable by idealised user models in an objective, stable world. In a study of people's use of a copying machine, she used video technology to capture as much as possible of the situation, and rather than a predetermined coding scheme she used conversational analysis. Thus, she devised a process that was open to discovery of unknown conditions and relationships. During this thesis process, I have adapted a similar approach by using inductive analysis methods and an iterative, user-involved design process.

> Because the hunch is that the structure lies in a relation between action and its circumstances that we have yet to uncover, we don't want to presuppose what are the relevant conditions, or their relationship to the structure of the action (Suchman, 1987, p. 75).

Research design, methods and analysis

This chapter describes the methods used throughout the research presented in this thesis. Table 1 outlines the methods used to collect and analyse data to fulfil the purpose of each paper. To provide context, the following text describes the progression of the thesis with an emphasis on the role of the methods.

Table 1. Overview of study methods presented in the included papers including their purpose and methods for data collection and analysis.

Study	Purpose	Participants	Data-collection	Analysis
I	To review past applications of virtual nature for therapeutic purposes and to contemplate potential future applications.	N/A	Narrative review	Qualitative analysis
II	To identify, implement and test older adults' preferences and ideas through their collaboration in a human-centred process to design a VNE prototype.	9 women, 5 men, 69-90 (M=75, SD=5.9, Median=73) years old.	Concurrent and retrospective think-aloud protocol; Questionnaires SUS, IMI, VRSQ[7] and background.	Qualitative content analysis; Descriptive statistics
III	To measure psycho-physiological effects of a VNE on older adults in the context of acute induced stress response in a laboratory setting.	22 women, 22 men, 65-91 (M=74, SD=5.5, Median=74) years old.	Sampling saliva for cortisol concentrations; Questionnaires STAI, IMI, and IPQ[7].	Mixed Factorial ANOVA; Descriptive statistics
IV	To explore what meanings residents and staff make of using different types of VNEs in a residential care facility.	4 women, 3 men, 67-91 (M=82, SD=9.8, Median=88) years old.	Observations and interview	Qualitative Content Analysis
V	To investigate how the long-term use of VNEs at a residential care facility can become a meaningful activity.	3 women, 4 men, 71-97 (M=83, SD=9.4, Median=81) years old.	Observations	Framework Analysis

[7] System Usability Scale (SUS) (Brooke, 2013), Intrinsic Motivation Inventory (IMI) (McAuley, et al., 1989), Virtual Reality Symptoms Questionnaire (VRSQ) (Ames, et al., 2005), State-Trait Anxiety Inventory (STAI) (Spielberger, 1983), Igroup Presence Questionnaire (IPQ) (Schubert, et al., 2001)

Study I

In the beginning of my thesis work, I participated in a narrative review paper (Paper I) that reviewed past and contemplated potential future applications of VR for therapeutic purposes. Being a narrative review, it did not follow a strict predetermined search strategy or protocol (Sukhera, 2022). Instead, its flexible approach allowed for the exploration of a wide array of topics in a multidisciplinary landscape. Thus, the authors reviewed existing literature seeking to answer *whether engaging with virtual nature can contribute to enhanced well-being in house-bound or mobility-constrained individuals*. The review encompassed a very broad spectrum in terms of types of VR (e.g., including semi-immersive), therapeutic application (e.g., pain management, stroke rehabilitation, phobias, eating disorders, etc.), population (e.g., all demographics), and it considered any types of virtual environments, albeit with special attention to those that included nature in some form. In addition, it contemplated the applicability of VR to a set of proposed mediating mechanisms linking nature exposure and well-being.

The results of Paper I showed that there are indeed many different possibilities to put VR to good use in healthcare, and proposed that VR can play at least some role in all the suggested mediating mechanisms between nature and health. Thus, it concluded that virtual nature can be an alternative to real nature contact when such is not possible and thus added to the notion of VNEs in residential care facilities as a feasible venture. Some researchers might say that the natural course of action to proceed from here should be to go ahead and put these proposed mechanisms to test using VR. However, as is evident from the diversity of the studies found in Paper I, VNEs can exist in so many forms; it is not simply a matter of virtualising nature (e.g., you must choose a subset of technologies, environments, and interactions). In addition, coming from such a broad scope, many of the proposed mechanisms are just not as applicable or relevant in the context of residential care facilities. For those, and other reasons that permeate the above chapters, my reasoning was that it was premature to quantitatively assess the efficiency of VNEs at care homes. Thus, I chose to proceed by taking a step back, and set out to explore what VNEs could become in the hands of older adults, and how and why.

Study II

To begin my exploratory journey, I did not feel quite ready to venture out into the wild and test VNEs at residential care facilities just yet. We needed to have something with us that I had not just taken off the store shelf. There were VNEs that had been used in research that I may have been able to get hold of, but those were from non-VR related frameworks and/or non-participatory designs. Thus, we

invited older adults to design a VNE prototype in a collaborative, human-centred, iterative process (Paper II). Their preferences and ideas guided the design, and the iterative nature of the process enabled the participants and us to generate and test design concepts incrementally.

Fourteen participants were recruited via retiree organisations. The inclusion criteria given were: 65+ years old; Swedish speaking; have adequate eyesight to watch television; and able to travel to the lab. The exclusion criteria were: propensity for dizziness or motion sickness; problems with balance; dementia or impaired cognitive function. The sampling was both purposeful, since the participants were selected with their lived knowledge and insight in mind, and convenient, since they were selected by choosing to respond to our outreach rather than being randomly selected by us (Koerber & McMichael, 2008). All participants were invited to individually come to the lab where they were asked to test a prototype, complete questionnaires and contribute their ideas and preferences for what and how the VNE should be and what they should be able to do in it. An adapted concurrent and retrospective think-aloud protocol (Ericsson & Simon, 1993) was used to allow participants to freely speak their mind. The following standard questionnaires – System Usability Scale (Brooke, 2013), Intrinsic Motivation Inventory (McAuley, et al., 1989), and Virtual Reality Symptom Questionnaire (Ames, et al., 2005) (translated to Swedish) – were used to measure usability, affective aspects, and side effects. In addition, we constructed our own background questionnaire to gather information on the participants' access to nature, as well as their experiences with both nature and VR.

Figure 3. Retrospective think-aloud session.

During think-aloud sessions, the participant was asked to freely speak their reactions, ideas, preferences, or any thoughts about the VNE and potential future versions. When necessary, I used directive and non-directive probing techniques to encourage the participant to cover yet unaddressed aspects or to elaborate some things (Moerman, 2010). Concurrent think-aloud sessions took place while the participant was using the VNE. During this, a video recorded the participant with an overhead side-shot along with their view of the VNE displayed in a picture-in-picture format. Retrospective think-aloud sessions were conducted afterwards as the participant and I watched the video of the concurrent think-aloud session (Figure 3). While the concurrent sessions leaned more toward immediate reactions and spontaneous reflections, the retrospective sessions allowed for deeper, more thoughtful elicitation. Study II proceeded throughout three iterations with additions and changes to the prototype based on the participants' input in between (Figure 4).

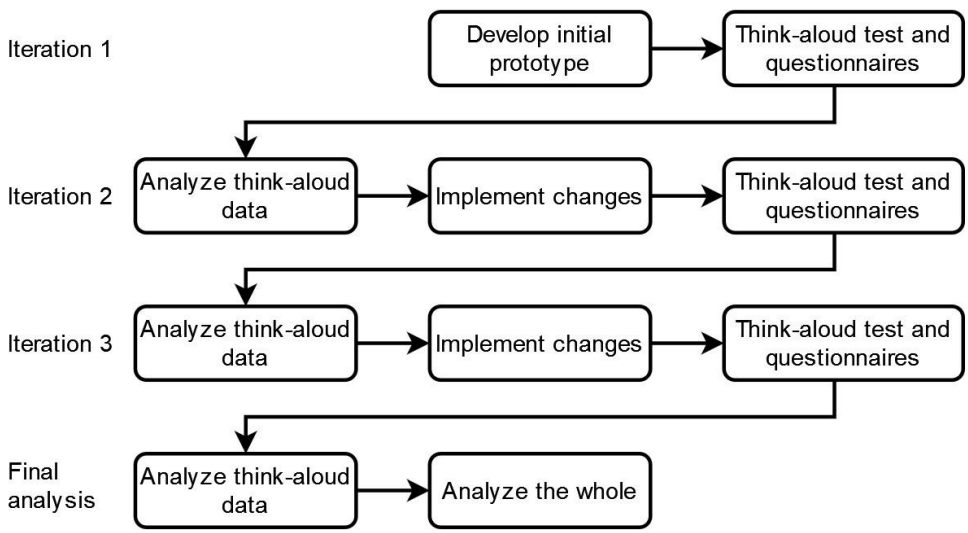

Figure 4. The iterative procedure of Study II

Thus, each participant (with some exceptions) came to the lab three times and saw it gradually evolve. By experiencing their preferences and ideas embodied in the prototype, they were able to validate and expand upon their initial input. To analyse the data from the think-aloud sessions, we used a qualitative content analysis method inspired by Graneheim and Lundman (2004). To visualise the distribution of answers and thus promote the visibility of individual participants in the data, we used boxplots and employed an exploratory mindset, which allowed us to discover unanticipated patterns in the data (Tukey, 1977). As a final step, we continued the analysis with a heightened attention to the latent content, focusing on the underlying threads of meaning running through all the data (this step is referred to as "Analyse

the whole" in Figure 4). Study II resulted in a set of principles for VNEs that were used in the design of a second prototype that we named *VR Island*.

Study III

Although I still felt it premature to test VNEs quantitatively on a large scale for any mediating mechanisms or medical applications, we nevertheless decided to put the prototype to the test in a small quantitative lab study (Paper III) for one of the most promising proposed links between nature and health, namely stress recovery. The purpose of Study III was to measure the ability of a VNE we had developed (VR Island) to promote stress recovery from induced social stress. In the test, which included 44 older adults of both sexes, social stress was induced through a VR version of the Trier Social Stress Test (Figure 5), which is an established method for inducing stress (Kirschbaum, et al., 1993).

Figure 5. Virtual Trier Social Stress Test.

Thereafter, they were allowed to recover by exploring the VR Island VNE or by sitting, reading a magazine (control). Recruitment, inclusion and exclusion criteria were the same as for Study II, with the addition of recruiting through social media and the help of acquaintances and colleagues. Control and experimental groups were randomly selected with equal size (n=22) and distribution of age and sex. At given points throughout the experiment, saliva cortisol was sampled. The standard questionnaires (translated to Swedish) –State-Trait Anxiety Inventory (Spielberger, 1983), Igroup Presence Questionnaire (Schubert, et al., 2001) and Intrinsic Motivation Inventory (McAuley, et al., 1989) – were employed to measure stress/anxiety, sense of presence and affective experience. Peter Jönsson performed statistical analysis of the Cortisol and State-Trait Anxiety Inventory data using a mixed factorial ANOVA. Cortisol concentration and State-Trait Anxiety Inventory scores were within-subjects factors, because they were measured at specific points during the experiment (e.g., before and after stress induction and VNE exposure/control) for all participants. The between-subjects factor was VNE exposure, with half the participants experiencing VR Island, while the control group spent the same amount of time reading a magazine. Presence and intrinsic motivation were measured at the end of the experiment in those who experienced VR Island. The Igroup Presence Questionnaire and Intrinsic Motivation Inventory results were visualised using boxplots to reveal the distribution and encourage an exploratory mindset, potentially uncovering unexpected patterns (Tukey, 1977). Sure enough, the results from cortisol saliva concentrations analysis revealed that the VNE did not have the projected effect of improved stress recovery. Instead, we found an elevation of cortisol. By triangulating with the questionnaires, we found, surprisingly further, no perceived anxiety/stress or pressure, and high enjoyment and sense of presence during VNE use. We speculated that the sensation of VR caused excitement rather than stress/anxiety, something that may cause a surge in cortisol (Carré, et al., 2006; Flinn, 2006). Thus, it strengthened my notion that nature cannot simply be virtualised since VR comes with inherent intricacies, as described in previous sections (e.g., *Immersion and presence*, and *An inductive approach*).

Study IV

Finally, we went out into the wild to a special housing facility in Sweden, bringing with us different types of VR devices and environments, among them VR Island (Paper IV). Over a total of 8 visits, we had "VR coffee" with residents during which they tried different VNEs as we observed their reactions. In addition, we interviewed two of the participating staff members. We analysed the data using a qualitative content analysis method (Graneheim & Lundman, 2004). Recruitment was made by contacting the administration for special housing facilities in a municipality in southern Sweden. We chose this municipality for its relatively diverse population in

terms of socioeconomic background. Thus, we came in contact with a special housing facility where we had the chance to meet people that could participate in Study IV. Such were those who could speak and understand Swedish, with sufficient eyesight to watch television, cognitive ability to perceive the VNE and to answer questions about their experience, general fitness to be able to handle the VNE experience, and thus were reasonably potential to gain some benefit from the experience and not the other way around. Exclusion criteria were to be bedridden, have severe dementia, or be prone to motion sickness. To select potential participants, we relied on the care staff since they were familiar with the residents. The selected residents were approached with brief information about Study IV including general information about VR and what the study would involve in practice. Those who were interested received further information about Study IV, such as its purpose and their rights as participants regarding confidentiality and voluntarism. Thereafter, those who decided to participate were asked to sign their written informed consent.

Figure 6. VR coffee.

As mentioned, we had VR coffee (VR fika in Swedish) with the participants (Figure 6). VR coffee was a concept we created to frame the VR activity in a familiar and safe-feeling context. “Fika” is a deeply ingrained socio-cultural phenomenon in Sweden that involves people having a beverage, typically coffee, and often pastries or sandwiches. A VR coffee session typically lasted an hour, during which the participants tried different VNEs, including VR Island (see Papers II, III, and IV), and head-mounted VR display options. Thus, over the course of two weeks, the participants were presented with a thought-out program of devices and VNEs. The

projected demand on the participants would gradually increase in order for them to adapt with ease. While the two first sessions included other VNEs, the last two sessions featured our own VNE prototype, VR Island. These three VNEs differed in many ways, which allowed us to learn more about how different features work. During the sessions we wrote down our observations and recorded the audio for detailed review. After each session, upon the dispersion of the group, a staff member asked each participant a few open-ended questions about their experience. We arranged VR coffee sessions twice a week for two weeks with two groups (Figure 7). In between the groups, we paused for three weeks to make a preliminary analysis of our observations, and potentially make changes to the VR Island prototype and protocol. This allowed us to make use of what we had learnt thus far (e.g., usability issues and about the participants' experiences) and take the opportunity to try changes in the next iteration.

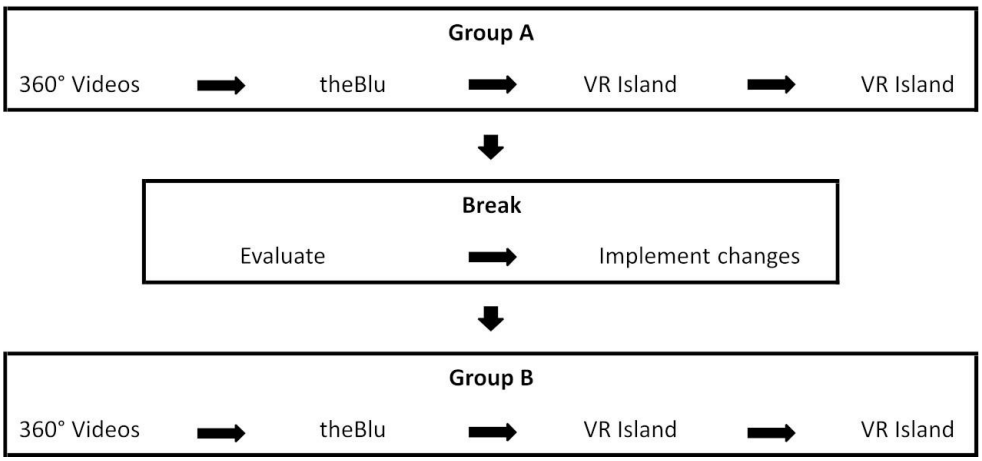

Figure 7. Procedure of Study IV

After the final session, we carried out a proper analysis. To triangulate (Denzin, 1978), we analysed all data sets (observations, interview and open-ended questions) as a whole. All members of the research team read through the data several times. Thereafter, I broke down the text into meaning units. While reflecting on their meaning, I grouped the units as categories and subcategories emerged. We discussed the analysis together and went back and forth revising the analysis and all authors reflecting in a group. Thus proceeded the analysis until we had reached consensus. In this way, we explored what meanings residents and staff made of using different types of VNEs and found that they can evoke joy, fascination, thrill, and aesthetic pleasure, and that more immersive and interactive VNEs may instigate more and/or stronger emotional responses. We also began to see a need for individual adaptations of the VNEs.

Study V

We performed a longitudinal study to learn what meanings older adults make of VNEs on the longer term, and how they can become a meaningful activity at residential care facilities. We contacted a Swedish municipality in southern Sweden and came in contact with a residential care facility. The selection and recruitment procedures were similar to those of Study IV. We organised VR coffee sessions (see Study IV) with two groups of residents and made changes to the VR Island prototype and 360° video content to follow the requests and preferences of the participants. Our initial plan was to offer one session a week per group for 6 months. However, after 4 months we were denied entry to the facility due to the COVID-19 pandemic. After another 6 months, restrictions were lifted somewhat, allowing one researcher (Maria Hedin) to make individual weekly visits to the participants in their private rooms. This restricted the VR technology use to the non-interactive, but highly portable 360° video format. For another 2 months, Maria Hedin was able to offer such videos to the participants, including bespoke videos that she filmed herself. In this way, participants were able to virtually visit places they referred to and had requested in conversations with Maria during their VR sessions. Our method of data collection was observation in line with Spradley (1980) (i.e., observing the place, the people and the activity in an open, unstructured way). We used the framework method as described by Gale et al. (2013) to analyse the data. All researchers read all the transcripts individually to get a holistic understanding. We coded three selected transcripts, identifying meaning units relevant to the research question. Over several meetings, we discussed and reflected the codes to reach consensus over a set of categories that constituted a preliminary analytic framework and then applied it to the remaining transcripts. During the ongoing analysis, the framework was refined as new codes and categories emerged. Mattias Wallergård then constructed a code/participant matrix for each category that captured how different codes were manifested in the expressions and actions of different participants. The matrix was used in regular team meetings for review and discussion. As a final step, we analysed the codes with a heightened attention to the latent content and generated a set of analytic memos. As a result, two themes emerged that cut across all categories, addressing the question as to how VNEs can be a meaningful activity in residential care facilities.

Ethical considerations

There has long been consensus that processes that affect people's lives should involve their participation (Arnstein, 1969). As participation is viewed as a virtue, there is a risk that this may lead to the inclusion of a participatory component merely to "tick the participation box". As previously discussed under *User involvement*,

participation can exist on a scale or "ladder" of participant empowerment that ranges from none to full. For example, user involvement can be manipulative, tokenistic, or empowering (Arnstein, 1969). In most of our studies, the participants were able to confirm that their input had been acknowledged, be it embodied in a VNE prototype or reflected in 360° video content filmed or selected for their individual VR sessions. Thus, participation should have been empowering for the participants. However, there is a risk that individual participants may have felt that their particular ideas and suggestions were not heeded to a satisfactory degree, making the participants feel ignored. Unfortunately, we did not ask about their experience in this regard during any of our studies. In future studies, it should be considered if such a question should be incorporated at regular points (e.g., during each VR session).

The study behind Paper IV, being a pilot study, featured only a minimal development component, only allowing for minor changes to the prototype in between two separate parts of the study. Consequently, only two of the participants were able to experience any changes. However, that particular study was not presented in a way that the participants would expect this.

During our studies at residential care facilities, we noticed how our interventions had a positive impact on some residents, which was, of course, fortunate. However, it also meant that when the studies were concluded and the VR sessions ended, these residents may have experienced a sense of loss – whether it be from missing a welcome distraction and moments of joy and fascination, or, perhaps most unfortunate, from missing the relationships that had formed over time. This potential negative effect did not go unconsidered by us. Thus, after the pilot study of Paper IV had concluded, we left behind some VR headsets that could be used by the residents and staff that had participated in the study. Similarly, after Study V had officially ended, one of the researchers (Maria Hedin) who had formed relationships with some of the residents, continued her regular VR sessions with the residents for as long as possible.

VR is known to cause nausea and other symptoms (Keshavarz, et al., 2014), often referred to as cyber sickness. It is theorised that the main contributing factor is inconsistency between the visual and vestibular senses. VR systems of today feature tracking of head and body movement and orientation so that such inconsistency can be mitigated. Still, if hardware performance is compromised, the hardware can fail to provide sufficient consistency, and nausea can occur. Therefore, we were mindful to use hardware that performed sufficiently for the software used. The VR we employed sometimes visually simulated movement that was inconsistent with the participant's movements, such as accelerations and decelerations as part of a system for moving greater distances. These were adjusted to be as careful as feasibly possible. In addition, our protocols consistently included steps to probe the participant for VR symptoms. Still, VR symptoms, such as nausea, can and did occasionally occur which risks causing participant discomfort. Other aspects,

related to the characteristics of the environment caused mild discomfort in participants, such as the steepness of the terrain.

Recruiting residents to research studies at residential care facilities is not unproblematic. As discussed under *Residential care facilities*, there can be a sense among residents to be forced to subordinate and conform to the will of the staff, and even adapt their person (Österlind, et al., 2016). We could not approach the residents directly during the recruitment phase of our studies at residential care facilities (Paper IV and V). Instead, the staff handled the selection and recruitment, based on the criteria we provided. Thus, researchers do not always have full insight into the recruitment process, raising the risk of passive participation. Also, there may be a tendency among some participants to carry on their participation even though they may not want to. As an example during Study V, one participant expressed her sense of duty to participate as she had initially agreed. Naturally, we reminded them that the agreement also states that they are fully within their rights to end their participation at any time, unconditionally.

Summary of papers

Table 2 presents the five papers that report the results of the research on which this thesis is based. It contains a brief encapsulation of the purpose and principal findings of each paper. A summary of the results of each paper follows.

Table 2. The purpose and principal findings of each paper.

Paper	Principal findings	Principal findings
I	To review past applications of virtual nature for therapeutic purposes and to contemplate potential future applications.	Virtual nature has the potential as an alternative to real nature when such contact is not possible. However, real nature contact should always be the preferred option.
II	To identify, implement, and test older adults' preferences and ideas through their collaboration in a human-centred process to design a VNE prototype.	The participants' preferences included trueness to reality in terms of: rendition and behaviour, the ability to explore and interact with the VNE, and to identify with it and relate to memories. Thus, we proposed three main principles of VNEs for older adults: realness, interactivity, and relatedness. We further proposed that VNEs should accommodate for diversity and ideally be tailored to the user.
III	To measure the psycho-physiological effects of a VNE on older adults in the context of an acute induced stress response in a laboratory setting.	Results indicated a surge in cortisol in the participants from the VNE use. However, questionnaire data suggested that it was caused by positive emotions such as excitement, interest, and enjoyment rather than negative emotions such as anxiety, pressure, and tension.
IV	To explore the meanings residents and staff make of using different types of VNEs in a residential care facility.	Results suggested that VNE use can evoke positive emotions such as joy, fascination, thrill, and aesthetic pleasure. More immersive/interactive VNEs instigated more/stronger emotional responses. VNEs should accommodate for different levels of use from passive observation to active exploration.
V	To investigate how the long-term use of VNEs at a residential care facility can become a meaningful activity.	At a residential care facility, a meaningful VNE for older adults is not a one-size-fits-all turn-key solution. It needs to be tailored to the individual. The person facilitating the VR (the "VR guide") is central. A meaningful VR intervention can develop in a positive feedback loop of building a VR guide- user relationship and tailoring the VR experience. It is like a back-and-forth where the resident, instigated by the VR experience reacts and shares their feelings, memories, and knowledge. Thereafter, the guide "responds" by adapting the intervention (e.g., acquiring relatable content) to subsequent VR sessions, and so on.

Paper I
A prescription for "nature" – The potential of using virtual nature in therapeutics

This narrative review was a broad first exploration for our research team of VR, with a special focus on virtual nature in health and care settings. It examined past applications of VR in contexts such as VR as pain relief, distraction and relaxation in cancer treatment, stroke and neurological disorder rehabilitation, and for promoting mental health and well-being. The review also considered nine underlying mechanisms proposed by a WHO report (World Health Organization, 2016) that may explain the benefits of having contact with nature, and assessed their applicability to VR:

- Improved relaxation and restoration
- Improved social capital
- Improved functioning of the immune system
- Enhanced physical activity, improved fitness, and reduced obesity
- Anthropogenic noise buffering and production of natural sounds
- Reduced exposure to air pollution
- Reduction of the urban heat island effect
- Enhanced pro-environmental behaviour
- Optimised exposure to sunlight and improved sleep

The findings suggest that VR could play at least some role in these mechanisms. Thus, the review concluded that virtual nature has the potential as an alternative when real nature contact is not possible. However, real nature should always be the preferred option.

Paper II
Designing virtual natural environments for older adults: Think-Aloud study

Study II sought to identify the preferences and ideas of older adults and how these could be designed and realised in a VNE prototype. We aimed to generate knowledge from the bottom up and not impose our own assumptions on older adults about their meanings of VNEs. Thus, we performed an iterative design process in

which 14 older participants tested the prototype and gave their preferences and ideas, while we intermittently made changes to the prototype. We used a qualitative interview technique called *Think-aloud protocol* (Ericsson & Simon, 1993) and standard questionnaires to measure usability, intrinsic motivation, and VR side effects (see Study II). The iterative process resulted in a prototype where many of the participants' preferences and ideas were implemented (Figure 8).

Figure 8. The VNE prototype of Study II.

In addition, we compiled the condensed preferences, ideas, and reactions in tables. After the final iteration, we performed a thematic analysis of the whole, condensing our findings into three main principles for VNEs for older adults*: realness*, *interactivity*, and *relatedness*. *Realness* entails: trueness to reality in terms of

rendition and behaviour; the perception of the VNE as a real place (e.g., through the ability to imagine a historical past); and the sense of presence by providing sensorimotor contingencies such as sideways head movements. *Interactivity* entails interaction with the environment such as the ability to explore/roam and activities such as picking apples. *Relatedness* entails familiarity, the ability to identify with the environment and relate to memories. We also concluded that, given the high diversity of preferences for content and activities that were revealed among the participants in Study II, VNEs should be designed to accommodate such diversity.

Paper III
Endocrine effects of an interactive virtual natural environment on older adults

The purpose of Study III was to examine a VNE's potential to affect the short-term ability in older adults to recover from social stress. The VNE used was VR Island (Figure 9), which was developed by the thesis author and was based on findings from the iterative qualitative Study II previously presented. VR Island was constructed using the *Unreal Engine 4* game engine and thus it utilised real- time 3D graphics. In Study III, the VNE was experienced via an *HTC Vive* HMD tethered to a desktop PC with an *Nvidia GTX 1080* video card. The VNE was an island comprised of various environments that a user could explore using seated torso-directed steering in a swivel chair. Forty-four older adults of both sexes were subjected to a virtual version of the *Trier Social Stress Test* (Jönsson, et al., 2010) with the intention to induce social stress. Directly following, they were allowed to recover – half of the group using VR Island and the other half, the control group, without any VR stimuli. To measure stress, we sampled saliva cortisol at given times during the test. To also measure affective aspects, side effects, subjective stress and presence, we used the four questionnaires: 1) Intrinsic Motivation Inventory (McAuley, et al., 1989), 2) Virtual Reality Symptoms Questionnaire (Ames, et al., 2005), 3) Spielberger's State-Trait Anxiety Inventory (Spielberger, 1983), and 4) Igroup Presence Questionnaire (Schubert, et al., 2001).

We hypothesised that we would see a faster decline of cortisol in the VNE group during the recovery phase. To our surprise, we found the opposite: significantly higher cortisol levels in the VNE group, which would indicate that VR Island induced anxiety/stress. However, the Intrinsic Motivation Inventory scores showed high interest/enjoyment and low pressure/tension. Furthermore, the State-Trait Anxiety Inventory scores showed no increase in perceived anxiety in the VNE group compared to the control. It has previously been proposed that an acute surge in cortisol can result from positive affect and fun and exciting experiences, such as in children on Christmas Eve (Flinn, 2006), or adults engaging in sports activities

(Carré, et al., 2006). Thus, we found it reasonable that the elevated cortisol levels reflected excitement rather than anxiety. The Igroup Presence Questionnaire results indicated a high sense of presence while exploring the VNE. As previously presented, presence relies partly on the illusion that you are physically in a different place (place illusion) (Slater, et al., 2022). Immersive VR that provides adequately accurate responses to perceptual actions can cause perceptual place illusion. Paper III thus suggested that the sensation of being in a different place, while at the same time being aware that it is an illusion, contributed to a sense of excitement, which in turn contributed to invoking a surge in cortisol.

Figure 9. Some views of the VR Island prototype.

Paper IV
Designing virtual natural environments for older adults in residential care facilities

An artefact exists in a network of stakeholders (Krippendorff, 2006) and they form their meanings of the artefact in communications with each other. Thus, a resident's experience of a VNE at a residential care facility is affected by the perception of others, such as other residents, assistants, activity workers, nurses, and next of kin of residents. The residents are not the only users. For example, most residents' VNE activities will likely involve one or more assistants. Likewise, all kinds of circumstances in the stakeholders' situation matter, which is why it is vital to

involve stakeholders *in* their context. Thus, the purpose of Study IV was to test VNEs with real users at a residential care facility. In this study we held regular VR coffee sessions with two groups of residents with at least one assistant present (see Study IV). We used a qualitative method, collecting data through direct observations and analysed the data using qualitative content analysis. The results of Study IV showed that VNE use can arouse positive emotions such as joy, fascination, thrill, and aesthetic pleasure in residents of a care facility. More immersive/interactive VNEs activated more and stronger emotional expressions than less immersive/interactive VNEs. We also observed an increase over time in confidence, skill and enjoyment in using VNEs, and an increase in social interaction among the residents. Based on the diversity in the participants' approaches and reactions while using VNEs, Paper IV proposed that VNEs should accommodate for various levels on a scale from active exploration to passive observation, and for individual preferences for content.

Paper V
Introducing virtual reality as a meaningful activity in a residential care facility – a direct observation study

The purpose of Study V was to investigate VNE use by older adults in residential care for a longer term (6 months in total). As in the study presented in the previous section, we organised VR coffee sessions with two groups of 4/3 residents. Due to restrictions in connection with the COVID-19 pandemic, we also incorporated the use of 360° video and untethered HMDs (Oculus Quest) during individual visits in the residents' rooms. We used a qualitative method to collect data through direct observation and analysed the data using the Framework Method (Gale, et al., 2013). Our research question was how virtual nature environments can be experienced as a meaningful activity in nursing homes. Two central themes emerged: *Individual Adaptation* and *Qualified VR Assistance*. The path to a meaningful VNE experience was quite different among the participants and during the study it became apparent that the VNE experience should be adapted to the individual. Several sub-themes emerged that represent different aspects of adaptation: *Individualised world-building*; *Individualised realism*; *A VNE that relates to the person's interests and identity*; *Challenges and affordances*; *Group composition*; and *Assistive VR devices*. In addition, we identified a cyclic self-reinforcing process where the VR experience evokes memories and emotions and instigates the user to react and share their thoughts, feelings, and knowledge. Based on these expressions, the VR guide (a real person, not software) can tailor the VR intervention to the user's preferences and needs. Meanwhile, the relationship between the VR guide and the user progresses and as a result, the VR guide's knowledge of the user improves. The degree of

presence, trueness to reality, coherency, relatedness, replayability, technical fidelity (e.g., field of view and resolution), participant group composition (when applicable), are all variables that in relation to the individual user's traits affect intrinsic motivation, perceived affordances, and agency. Current VR technology is not accessible to older adults in residential care facilities. Qualified VR assistance and custom technical solutions are required to bridge the gap between the human and technology. The VR guide needs to be well versed in VR and know the user's personality, interests, and capabilities.

Discussion

In the research process, we discovered several ways in which older adults at residential care facilities find VNEs meaningful. We have identified several factors that influence meaning making in both the VNEs and in how they are used. We have also discovered how VNEs can be used in a meaningful way in residential care facilities. An example is how it can contribute to person-centredness in older adult care.

RQ 1: What meanings do older adults make of VNEs?

As observed during these studies, older adults at residential care facilities can find VNEs meaningful as:

- A stimulating, enjoyable mood-improving experience
- A source of a range of positive emotions
- A means to trigger memories and reminisce about past events, and to inspire curiosity and reflection
- A distraction from current challenges and from dwelling on negative thoughts
- An empowering and control-enhancing activity
- A catalyst for relation building and sharing

During the think-aloud sessions in Study II (Lundstedt, et al., 2023), participants described various aspects of the VNE that reflected a stimulating and enjoyable experience (Figure 10). Likewise, although the expressions were different during the VR coffee sessions of Study IV (Lundstedt, et al., 2021), the participants conveyed positive emotions while using VNEs. These were expressed non-verbally through smiles, giggles, and laughter, as well as verbally by expressing feelings of joy, fascination and awe, and pleasure from the aesthetic experience. This emotional response was also noted in Study V (Paper V) where VNEs were found to evoke feelings of wonder, joy, delight, amusement, and thrill.

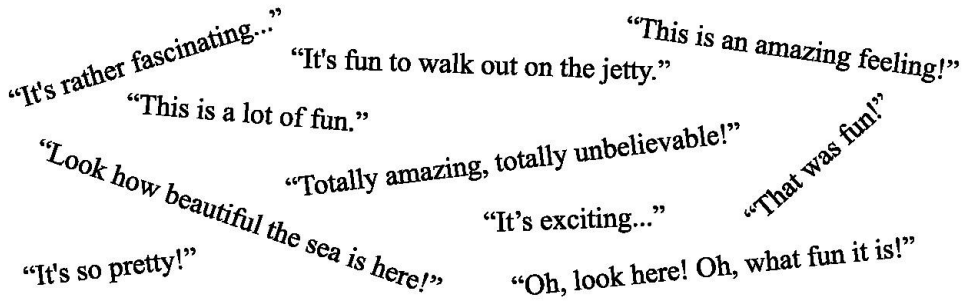

Figure 10. Verbal expressions from Studies II, IV, and V illustrating the potential of VNEs as a stimulating and enjoyable experience.

Appel et al. (2021) found similar reactions of enjoyment. Restout et al. (2023) found in their scoping review that studies of VR (not specifically nature based though) at residential care facilities highlight the positive effect on emotion.

Already during Study II (Lundstedt, et al., 2023), the meaning of a VNE as a place to feel at home, recognise oneself, and evoke memories surfaced prominently. This was reflected noticeably in the participants' expressed preference for a familiar and relatable environment.

> Where I used to walk when I was a child, for example, I think would be a very nice experience . . . Because then you get it related directly to yourself. (Lundstedt, et al., 2023, p. 14)

This kind of meaning did not surface during Study IV (Lundstedt, et al., 2021), which I suspect is related to the short duration of the study. It may not have allowed enough time for the participants to move past the initial excitement and novelty of the virtual environments to explore their deeper meanings. During Study V (Paper V) however, over the total of 6 months that elapsed, the usefulness of the virtual environments as an instigator for reminiscence and reflection became most prominent over time. Appel et al. (2020) also saw an eagerness to reminisce about their memories, triggered by an immersive VR experience. Although the role of the VNEs to raise curiosity and as a subject for exploration surfaced in Studies II, IV and V, this was mostly expressed in Study II (Lundstedt, et al., 2023), which is natural given that it was a fundamental topic during the early phases of the research.

> You stop if there is something that you find interesting . . . and you think "exciting," and I want to see what that looks like . . . you want to inspect it closer. (Lundstedt, et al., 2023, p. 10)

Because Study IV extended over such a short period, even though we became somewhat familiar with the participants, we were not able to go fully into depth

about their meanings of VNEs. However, forming relations with the participants over a longer time during Study V (Paper V), meanings related to deeper layers of feelings and thoughts surfaced. For example, the VNE as a distraction from current challenges and from dwelling on negative thoughts, as the following quote by a participant of Study V reflect:

> The sense of time disappears. You get other things to think of than your diseases and how ill you are. The world becomes a little bigger.

During Study II (Lundstedt, et al., 2023), interactivity was proposed as an important principle for VNEs. Beyond basic perception-actions, such as shifting your head and body to perceive the space (see *Immersion and presence*), participants valued active exchange with the environment:

> I think it's good that you can do something, that you can drive in the boat, pick apples, walk around a little, that it doesn't become just a passive experience. (Lundstedt, et al., 2023, p. 11)

> You feel involved, active, that you can do something yourself. (Lundstedt, et al., 2023, p. 11)

> I affect something [in the environment]. It enhances the experience. (Lundstedt, et al., 2023, p. 11)

The notion of VNEs as an empowering and control-enhancing activity then surfaced in Studies IV and V: this stemmed from the ability of participants to have control and agency within the virtual environment (e.g., steering and interacting) (Lundstedt, et al., 2021), and from their ability to co-shape and integrate the virtual environments into their lived realities through their exchange with the VR guide (Paper V). During these exchanges, the virtual environment was the catalyst for relation building and sharing, which by my account is the most important finding during these studies and will be discussed in greater depth in the following chapters.

RQ 2: What factors influence meaning making?

During the study described in Paper II (Lundstedt, et al., 2023), three principles for VNEs emerged: *realness*, *interactivity*, and *relatedness*. I propose that these principles are influential in making VNEs meaningful for older adults. *Realness* entails: 1) trueness to reality in terms of rendition and behaviour, 2) the perception of the VNE as a real place (e.g., through the ability to imagine a historical past), and 3) the sense of presence by providing sensorimotor contingencies such as sideways head movements. The following quotes by participants reflect this:

> It would be very interesting to sense that feeling [touch the rock] . . . For me, it would be very positive. Because then I am absolutely in nature. (Lundstedt, et al., 2023, p. 14)

> You stop enjoying it, lose interest in it . . . when you go into the details and it is incorrect. Then it's maybe a little lesser of an experience. (Lundstedt, et al., 2023, p. 14)

> Here has been a house, and there you can see an old apple tree . . . it triggers the imagination, that someone has lived here and how were they doing? How were they able to live here in the middle of nowhere? Such things can also contribute a little. (Lundstedt, et al., 2023, p. 14)

As previously discussed under *Immersion and presence*, Slater et al. (2022) present the related concepts *place illusion* and *plausibility* as a prerequisite to *presence* in VR. In an environmental psychology context, realness brings to mind the two concepts *being away* and *extent* (mentioned under *Natural environments and virtual reality*) of Attention Restoration Theory (Kaplan, 1995).

Interactivity entails interaction with the environment such as the ability to explore/roam and manipulate the environment (e.g. picking apples). As one participant expressed:

> I affect something [in the environment]. It enhances the experience (Lundstedt, et al., 2023, p. 11).

It should be noted, though, that among the activities preferred were also passive activities, such as sitting, relaxing, and enjoying the scenery.

Relatedness entails a familiar environment that one can relate to and reminisce about. Other studies parallel a preference for familiar content in VR (though not necessarily nature-based VR) (Appel, et al., 2020; Restout, et al., 2023). In Study V, we found how the paths to a meaningful VNE experience diverged among the participants, calling for individualised adaptation. We found several influential factors that should be considered for the individual such as:

- *Individualised realism* – entails that participants have different backgrounds and references, affecting their expectations and perceptions of realism in a VNE.
- *A VNE that relates to the person's interests and identity*.
- *Challenges and affordances* – a suitably challenging experience which entails adapted affordances and signifiers in the environment.
- *Group composition*

- *Assistive VR devices* – off-the-shelf VR devices are often not accessible for older adults in residential care facilities.

Residents possess unique abilities and conditions, so adapted devices should exist for individual consideration. Other studies provide further evidence of usability issues associated with VR devices in residential care facilities (Holloway, et al., 2024; Ijaz, et al., 2022). As an example, Baker et al. (2020) found significant difficulties in using VR hand controls by individuals. As an example of an adapted VR device, de'Sperati et al. (2023) used augmented gaze to ease visual exploration during virtual biking with older adults. As can be seen in the bullet points just above, the principles of Paper II resurfaced in new forms with the added consideration of individualisation. We are not alone in the research community in calling for individualised VR experiences (Appel, et al., 2020; Baker, et al., 2020; Hung, et al., 2023; Waycott, et al., 2022).

Beyond the factors already presented, a key insight is that the meaning and effectiveness of VNEs go beyond the inherent design or principles and are, in fact, co-constructed through communication and interaction with others. In Study V, we also found the person administrating VR (the VR guide) to be instrumental. As the VR guide acquired knowledge of the user, they were able to adapt the experience to the individual. Thus, the VR guide was involved in populating the virtual environment with meaning. But it is my interpretation that it is not just about making the virtual environment relatable to the user, but also about having someone to share reactions and thoughts with. Someone who reflects a person's human experience – a witness to what they have experienced in the virtual environment (and, by extension, in their life, which the experience has brought to mind, and thereby their identity) – and with whom a relationship can form around these experiences. Thus, the real potential and richness of VNEs materialise when there is active engagement and meaningful communication involving other actors, such as the VR guide. The shared experience, dialogue, and interpretation among individuals contribute to the construction of the perceived reality within the virtual environment. Thus, the success of VNEs is not solely dependent on the inherent design or predefined principles. It is also deeply influenced by the collaborative and communicative aspects of the users and facilitators involved in the virtual experiences. If reality is constructed in communication with others (Krippendorff, 2006), perhaps this becomes extra important in a virtual environment – that someone else confirms that one has been there. This may be influential for the opportunity for someone to obtain the feeling that, as one of our participants said, "In memory, I have been on a real beach".

RQ 3: How can VNEs be used in a meaningful way in residential care facilities

In Study II, participants expressed a preference for a familiar VNE that they could identify with and relate to memories. Then in Study V, which took place in a residential care facility, we found that relatable content prompted the participants to open up and share memories, something that often evoked various feelings and thoughts in the VNE user. Sharing brought understanding and empathy to the VR guide and strengthened the relationship between the VR guide and the VNE user in a cyclic self-reinforcing process. As the VR guide gets to know the VNE user, the VR guide can provide an increasingly more tailored experience to the VNE user in terms of realness, relatedness and interactivity, along with the other factors that influence meaning making presented in the previous section. As an example, where does the VNE user exist in the Lawton and Nahemow's model (Lawton M. P., 1986)? How can the VR guide best provide a level of challenge that places the VR user in the zone of tolerable affect. For example, can the user explore or roam the environment through a seated torso directed steering, if they wish to? What assistance does the user need? And what virtual activities are congruent with the user's identity? What places and types of environments does the user want to visit? What level of realness/flavour of realism is acceptable for the user? As we have observed, there can be a trade-off between interactivity and realness. On the one hand, a real-time 3D graphics type of virtual environments can best provide a sense of being in place by providing sensorimotor contingencies (Slater, et al., 2022). Furthermore, it may promote plausibility by enabling the environment to socially respond to the VNE user's actions and thereby acknowledge them. On the other hand, if the VNE user has expert knowledge about some of the elements of the VNE in question, such as appearance, lifecycle and habitat of the flowers, a real-time 3D solution may not be viable to produce an accuracy that can uphold the plausibility for that user. This can have the effect that the VNE user stops caring and loses interest (Paper II). In such a case, a 360° video solution may best serve the experience. However, the user's sense of presence will most likely suffer since 360° videos can provide no sensorimotor contingencies other that looking around you with your neck stuck in one location. Since it is based on filmed material, there is no possibility for the user to interact with the environment, and it likely becomes a passive experience. Real-time 3D graphics on the other hand, have the potential to provide the user with a sense of agency as they can directly control where to go on their own initiative (Jeunet, et al., 2018).

The sense of agency

The sense of agency is the sense that you are in control – that the actions you take are not something that just happens, but that "I am the one who is causing or generating an action" (Gallagher, 2000). Unfortunately, many older adults experience a reduced sense of control (Wolinsky, et al., 2003). This can cause a person to take less responsibility for their health and be less likely to engage in health protective behaviours, negative neuroendocrine responses, and can inhibit immunologic function. The reduction of sense of control in older adults is likely caused by having fewer control-enhancing experiences and more control-restricting ones (Wolinsky, et al., 2003). Older adults residing in residential care facilities likely have control-restricting experiences daily, and few control-enhancing ones, due to their continual need of assistance. Österlind et al. (2016) reported negative feelings in residents of having to subordinate to the routines and norms at the residential care facility.

I propose that real-time 3D VR can contribute a sense of agency and a high sense of presence and can have the potential to provide control-enhancing experiences. An example is by allowing a person with limited mobility to steer themselves and go wherever they want in a virtual environment, where they would otherwise need assistance in the real world. In time, such control-enhancing experiences may increase a person's sense of control. During our studies at residential care facilities, we occasionally observed that it took some time for some of the participants to realise that they were able to take control and make requests. Gradually, we saw how initiative and agency started to show in users, at least in our VR sessions. Granted, this was probably a combined result of becoming increasingly familiar with us. Still, I find it reasonable that acquiring the ability to steer and go wherever you want in a virtual environment may contribute to a sense of regained control for some. Baker et al. (2020) present similar reflections around agency in VR.

> These results also hint at the ways in which future interactive VR systems might be developed in such a way as to "give back" a sense of control and agency that can be lacking in the institutional setting of a [residential care facility] (Baker, et al., 2020, p. 10).

Although 360° videos provide very limited possibilities for interaction, they can still, if used correctly, provide good opportunities for relatedness for the individual user because the VR guide can head out and film places that the users refer to in their VR sessions. This way the users may still have a control-enhancing experience in that they have, albeit in a different way, decided where to go (beyond simply choosing between the various alternatives of environments presented to them). Holloway et al. (2024) identified "agency in the choice of the nature and content of the VR experience" (p. 11) as an influential factor on a positive VR experience at residential care facilities.

Individualised adaptation

In this thesis research, we have at several turns arrived at the need for individualised adaptation of VNE activities to accommodate the person's needs and preferences. Similarly, Hung et al. (2023) in their scoping review propose a person-centred approach to VR at aged care settings:

> Careful adaptions are required to meet the unique needs of the older individuals living in aged care settings. (Hung, et al., 2023, p. 1)

Hung et al. (2023) envisioned an iterative co-design process where residents participate in the design and evaluation of VR interventions. This is similar to the cyclic self-reinforcing exchange between the VR guide and the VNE users that we have described, and the fundamental approach of this thesis to involve older adults in the design process.

Relation building

We are not alone in identifying VR as a relation building activity. Wilding et al. (2024) highlight how VR acted as a space for exchange of care between the staff and resident and how already existing care relations were activated (e.g., in how a personal engagement was activated when contemplating the relatability of the content). As this comment by staff reflects:

> I'm just trying to think of stuff at the moment that they would like, because I just don't think they realise what the VR is capable of. (Wilding, et al., 2024, p. 5)

The Wilding et al. (2024) study also demonstrated that beyond the resident and staff, broader social networks played a role in the meaning making of VR technology. Consistent with Krippendorff's view (2006), meaning emerged in communication between residents, staff, and their respective family members, as they offered care and support in the context of the VR experiences.

Risks of immersive VR

The interest in using VR to promote mental and cognitive health in older adult care is rapidly increasing (Flynn, et al., 2022; Skurla, et al., 2021). However, I advise caution in providing immersive VR to fragile users (e.g., those that experience detriments in cognitive and/or mental health) because VR has the potential to provide powerful illusions and strong reactions. For example, recall the elevated cortisol concentrations from Paper III and the emotional, albeit mostly positive, reactions by participants in Paper IV. Waycott et al. (2022) raised concerns about the realness of highly immersive VR and the potential negative or even harmful

experiences in users, such as fright and trauma, and they advocate for significate care and attention. Slater et al. (2020), in their opinion article about the ethical considerations of VR, speculate about worst-case negative outcomes of repeated exposure to virtual or augmented reality (i.e., Extended Reality[8] [XR]) with strong place illusion and plausibility. For example:

> Participants [may] remember virtual events as if they had been real, and fail to distinguish over time events that really happened and those that happened in XR (Slater, et al., 2020, p. 6).

In most cases, a person's cognitive and perceptual abilities help to keep virtual and actual realities separate. However, if these abilities are affected (e.g., from mental or cognitive unhealth, or reactions of psychotropic medications (Lorenz, 2020)), an individual may be more prone to confusion between real and virtual events. In Study V we observed this play out, as some participants appeared to confuse virtual and actual reality. However, we observed no apparent ill effects of such confusions. One person believed she had been out sailing for real with the VR guide according to a recount by a relative of their conversation. The relative described it as a recollection of a positive experience, as something that was beneficial for her well-being, and decided not to contradict her reality. According to Brooker (2004), a fundamental element of person-centred care is "looking at the world from the perspective of the person with dementia" (Brooker, 2004, p. 217). This entails taking a starting point in the person's subjective experience of reality in order to understand the person and meet their individual care needs. It is very important to never upset the person by reminding them of their memory impairments, or force a particular view of reality on a person, but instead talk about the things that they remember (Demenscentrum, 2018; Dietch, et al., 1989; Woods, 2002). Knowing if and how to intervene in a person's view of reality requires high perceptiveness and knowledge of the person. In this context, it is of extra importance for a carer that administers VR to a person with dementia to be well versed in the workings and potential effects of VR. Slater et al. (2020) further speculate:

> After an intense and emotional experience in XR, you take the headset off, and you are suddenly in the very different real world. We are not good at rapid adjustment of behavior and emotion regulation. (Slater, et al., 2020, p. 6).

According to Behr et al. (2005), re-entry from repeated VR exposure may potentially lead to cognitive, emotional, or behavioural disturbances.

[8] Extended Reality is an umbrella term for immersive technologies VR, Augmented Reality and Mixed Reality. While VR aims to block out the real world, replacing it with the virtual, Augmented and Mixed Reality overlays/blends digital content on/with the real world.

VR training

A VR guide should possess highly empathetic abilities along with strategies to safely deliver the person into the virtual world and back again to the real world. Therefore, I propose that it is important that people who administer VR in older adult care receive VR training. Slater et al. (2020) advocate training and education for the involved stakeholders about the power, positive aspects, and negative side effects of XR along with strategies for avoiding the latter. Given the rapid technological advances of VR, it is plausible that in the future VR will be indistinguishable from reality. This only further presses the importance of training and education of VR guides. Behr et al. (2005) have suggested strategies for coping with some of the ethical problems of VR. However, research is needed on strategies involving older adults in residential care facilities and people with cognitive and mental health challenges. Given all of this, VR training should not be seen solely as a precautionary measure, but also as an enabling, empowering tool that teaches VR guides about the possibilities and techniques of VR. This would increase their skills in providing individually adapted VR experiences, and at the same time boost their confidence, job satisfaction and professional pride. In a recent scoping review, Hung et al. (2023) identified *staff training* as a key facilitator for using VR in aged care settings. More studies highlight the importance of staff engagement (Waycott, et al., 2022; Wilding, et al., 2024). Concerns may be raised about whether resources exist to meet such engagement. Waycott et al. (2022) list *resource constraints and the problem of time* as a barrier to VR in residential care facilities. A comment by the staff illustrates effectively:

> In aged care we're all very time poor. So many people are off sick, everybody's running short. So yeah, the VR unfortunately isn't on the top of the list of things to do. (Wilding, et al., 2024, p. 4)

However, we do not yet know whether such engagement may actually decrease the workload of the staff, as has been shown when adapting a person-centred approach (Wijk & Edvardsson, 2020). A municipality in southern Sweden invested funds in a four month project to provide VR training to staff members of three of their residential care facilities (Burlövs kommun, 2023), which suggests that VR training is not an unfeasible endeavour.

Person-centredness

As we observed in Paper V, if organised in the proposed way, VR usage can promote relation building between a VR guide and VNE users. Thus, hypothetically, VR has the potential to promote a person-centred approach in older adult care where the staff takes on the role of VR guides. Relation building between the staff and the

person (and their next of kin) is instrumental in person-centred care (McCormack & McCance, 2017; Socialstyrelsen, 2017; Wijk & Edvardsson, 2020).

> When we are truly connected in a person-centered relationship we share our deepest sense of 'self', enabling others to know who we are as persons, what values are important to us, the dreams, hopes and desires we hold in our lives, and the kind of life that we strive to live. . . . Knowing the person in this way is essential to person-centered practice. (McCormack & McCance, 2017, p. 33)

In the person-centred approach, places such as the home region and other environments that the person has some emotional connection to are emphasised as important as they are saturated with memories that act as links to the person's history (McCormack & McCance, 2017). This corresponds well with our proposal of relatedness in a VNE. The tendency of VNE users to share memories, feelings and knowledge instigated by the VR experience, that was observed in Study V, may provide carers with authentic narratives, and thus promote their ability to provide person-centred care.

Although VNEs can support relation building and sharing if used in a person-centred way, this should not be seen as a single solution for implementing and maintaining person-centred care. This is because there is a lot more to person-centredness than that. In addition, there is no tool or process that fits every person or context (McCormack & McCance, 2017).

A model of a VR-user-assistant self-supporting cycle of meaningfulness

This tentative model is meant to describe our analysis of how VNEs can become meaningful at a residential care facility by using individualised adaptation and qualified VR guidance (Figure 11). When a person living at a residential care facility experiences being away in a different (virtual natural) environment, they may escape for a while their current situation and the troubles and worries they might have. They may find the experience pleasurable and awe-inspiring and may encounter relatable things that trigger memories and feelings. Such things invoke a desire to share reactions, stories, knowledge, and feelings. The person who administers VR (the VR guide) is qualified to safely deliver the person to and from the virtual environment and, to the necessary extent, act as a proxy agent for the user. The VR guide is also a recipient of the narrative that is gifted by the resident in the context of the VR experience. Over repeated sessions, the VR guide can use the information to adapt the VR into an increasingly more relatable and accessible experience (e.g., acquire relatable material such as 360° videos of the person's home environment). Meanwhile, a trust relationship is formed that further fuels the self-reinforcing

cycle. The VR-user-assistant system can also be seen as a vessel for traversing the person's life narrative, or a catalyst for relation building and narrative elicitation.

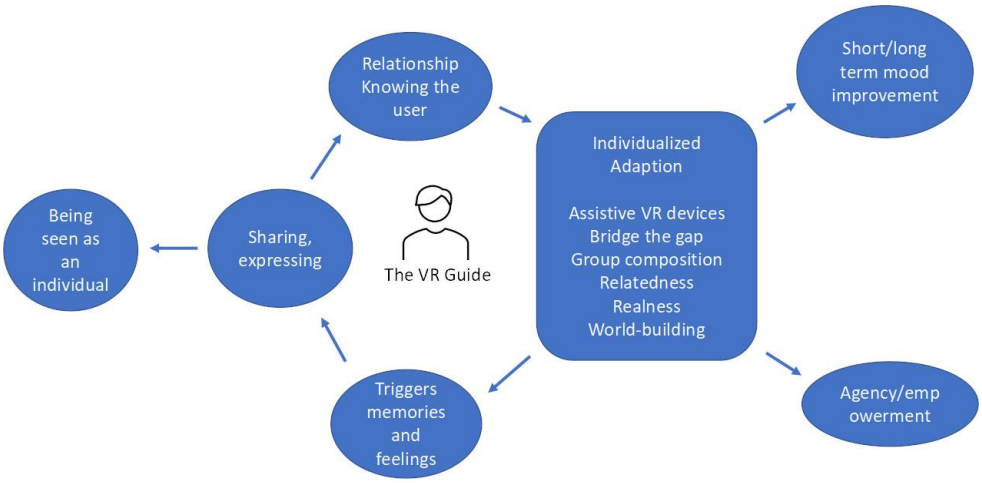

Figure 11. A model of a VR-user-assistant self-supporting cycle of meaningfulness.

Key take-aways for practitioners

Older adults in residential care facilities can acquire positive experiences from virtual natural environments if they are given the opportunity to select and use them in ways that suit them. As a user, one might feel joy, fascination, or even awe from how real the VR experience seems. One may experience a sense of being transported to another place and escape for a while from difficult circumstances, such as feelings of loneliness or a loss of control and identity. Things to consider include how the virtual environment aligns with the individual's previous experiences and identity, and how familiar, realistic, and authentic it feels to them.

Virtual natural environments may work as a catalyst for sharing and relation building by triggering memories, emotions and a willingness to share. For some, virtual natural environments may become truly meaningful only through engaged exchange with others, such as the person assisting and providing the VR – the "VR guide".

The VR guide needs to understand how VR can potentially affect a person in both positive and negative ways. Risks of immersive VR include nausea, negative emotions such as fright and discomfort. Some individuals may be prone to confusing virtual and actual reality. A skilled VR guide must know the person well to provide adequate support, be highly empathetic and attentive to their reactions, and skilled in delivering the person into and back from the virtual environment.

Virtual natural environments are not one-size-fits-all solutions with predictable outcomes. They rely on human engagement and derive their true value from meaningful interactions rather than serving as a way to save time or resources.

Strengths and limitations

One strength of this thesis research is that we have conducted our research within the context of residential care facilities, thus exposing us to the complex interplay of stakeholders and various conditions. This provided insights that helped make our findings applicable in a real-world practice.

Another strength is that rather than relying solely on off-the-shelf products that we could not modify, we developed VNEs ourselves in collaboration with the participants. This approach provided us with the flexibility and precision to explore aspects relevant to our research questions. It also allowed us to respond to new findings and unforeseen elements, enabling us to explore new directions in our research.

This thesis is part of a broader EU funded project with specific preformulated objectives and milestones. This structure brings certain expectations and conditions, which may have caused a certain inertia when it comes to reacting to unexpected findings and exploring new directions in research.

During Studies IV and V at residential care facilities, participants were selected based on their reasonable ability to potentially gain something meaningful from their involvement. It is also safe to assume that everyone involved was biased towards creating a positive experience for the participants. VR can be a way to achieve policy level goals of digitalisation, potentially generating bias in the organisation. These biases should be kept in mind, and we should not assume that VNEs can be beneficial for everyone, even if they are adapted to the individual.

During Study V, we had planned to collect physiological data, such as hair cortisol, blood pressure and sleep, and questionnaires measuring health related quality of life and mood. However, due to the COVID-19 pandemic, we were unable to complete these parts of the study, leaving it as a direct observation study. As a result, we missed out on data that could have provided a more comprehensive picture and revealed unforeseen conditions.

During these studies we have sometimes used translations of standard questionnaires. Due to time limitations, it was not feasible for us to validate the translated versions. Due to semantic and linguistic differences in the original language, translations affect how a questionnaire measures the intended concepts and ideas and will therefore compromise accuracy and comparability with other studies.

Risks

Perhaps the most obvious risk is that VNEs are used as a substitute for nature in cases where real nature would be preferrable to cut costs and save labour. I strongly posit that VNEs are not a substitute for nature exposure, rather a complement.

There is also a risk that residents feel pressured to use VNEs “for their own good”. Thus, I warn against pushing a solutionistic narrative around VNEs, especially in the context of the residential care facility. VNE usage should come from intrinsic motivation. In addition, assistants facilitating VR should acquire the skill to empower the user and support their agency.

Even worse, VR has the potential to be misused in an unengaged way to create time for other things (e.g., looking at one’s phone) while leaving the user to themself, potentially unsafe in the virtual environment. Or, as a way to passivate, making people easier to manage. VNEs should not be used with the intent to free time or resources. They require engagement.

Conclusions

The overarching aim of this thesis has been to discover/explore open-ended possibilities for VNEs for older adults from a human-centred perspective with a starting point in a VR context as opposed to an existing framework with VR added. A summary of the main conclusions of this thesis here follows:

- As observed during these studies, older adults at residential care facilities can find VNEs meaningful as: a stimulating, enjoyable mood-improving experience, and a source of a range of positive emotions; a means to trigger memories and reminisce about past events, and to inspire curiosity and reflection; a distraction from current challenges and from dwelling on negative thoughts; an empowering and control-enhancing activity; and a catalyst for relation building and sharing.
- Although this thesis proposes several principles for VNEs for older adults, such principles cannot be used to construct a one-size-fits-all turn-key solution that can be administered to the care receiver like a pill. The real potential of VNEs materialises in an activity that engages other actors (e.g., the VR guide) to instill it with meaning. Thus, the effectiveness of VNEs is not solely dependent on predefined principles and inherent design but on the active participation and engagement of those involved.
- VNEs have the potential to support a person-centred approach in older adult care if administered with individualised adaptation and qualified VR assistance as suggested by this thesis. Such a process involves VR as a catalyst for relation-building through the sharing of memories and emotions, and the co-shaping of virtual environments in relation to the resident's lived reality. At residential care facilities, VNEs can be meaningful as control-enhancing experiences, provided its capabilities to provide a sense of agency can be harnessed.
- Interventions such as restorative nature therapies should not be virtualised without careful consideration of the unique properties and conditions VR brings to the experience.
- This thesis furthers a human-centred framework for VNEs for use by older adults by contributing to an understanding of their meanings of VNEs, and how they may shape and appropriate VNEs into their lived realities. Such

understandings may be considered by researchers who seek to try specific outcomes of VNEs, or restorative frameworks in a VR context.

- This research may further contribute to the ongoing initiative in healthcare to foster a personalised approach that nurtures empathy and care on the person's terms and encourages caregivers to view the individual as a valued relationship with unique needs and qualities.

Future research

This thesis highlights several avenues for future research. The conclusions suggest potential directions that include more quantitative longitudinal interventions of VNEs in residential care facilities. Future studies could explore the feasibility, facilitation, design, and impact of both VR training for staff and individual adaptation of VNEs. Additionally, future projects may incorporate expanded sensory modalities such as olfactory (smell), haptic (touch), thermal, airflow, and full-body immersion. Research might also involve the exploration and development of adapted VR devices to accommodate for older adults' diverse abilities.

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