Going Out While Staying In

How Recreational Virtual Environment Augmentation Can Motivate Regular Exercise for Older Adult Nursing Home Residents

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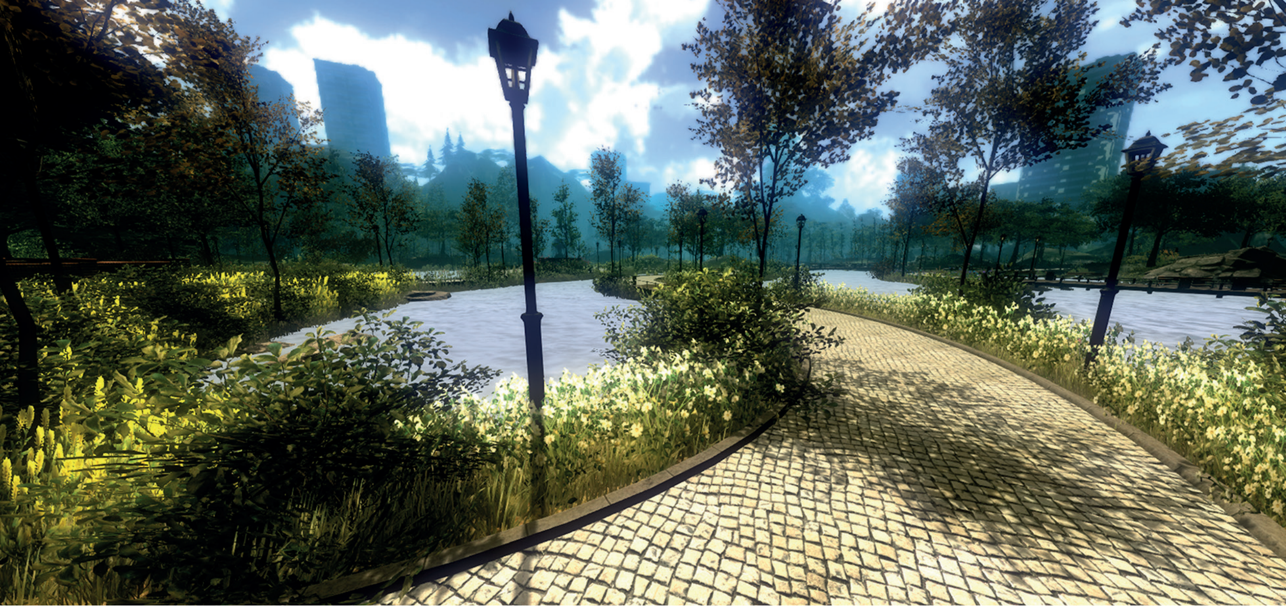

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BY
JON RAM BRUUN-PEDERSEN

DISSERTATION SUBMITTED 2016

AALBORG UNIVERSITY
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CV

Jon Ram Bruun-Pedersen received his B.Sc. in 2008 and M.Sc. in 2010 in Medialogy from the Department of Architecture, Design & Media Technology (ADMT) at Aalborg University Copenhagen. He onwards worked as Research Assistant until spring 2012, where he was appointed as a PhD Stipend at the Department of Architecture, Design & Media Technology at Aalborg University Copenhagen.

Dedicated to my wife Mette, and to my kids, Molly and Bastian.

You are my life.

ENGLISH SUMMARY

The world population is getting older. As our age increase, our body and mind start to lose its potency, until a point, where we lose independence, which means the ability to take care of ourselves unassistedly. To a certain degree, such old age symptoms are partly a function of lifestyle, and regular exercise can prevent physical and cognitive declines. For many seniors, nursing homes are the life that follows the loss of independence. Becoming a nursing home resident is a sign that the functional capabilities are now at an all-time low. Nursing homes are aware of this reality and offer in-house physical therapy rehabilitation for residents. However, old age makes many activities more challenging, including exercise. At Akaciegården nursing home in Frederiksberg, Denmark, residents have shown a lack of incentive to exercise, despite knowledge of the functional benefits, and an excellent relation to the therapy staff. In this dissertation, the lack of motivation to exercise was found to stem from a lack of enjoyment for the dominant exercise activity. Virtual reality (VR) technology is currently growing at a rapid rate, and so is the area of application. VR rehabilitation has the potential to enhance physical therapy activities, by contributing alternative types of feedback to activities through interactive, technological mediation, and thereby change the user's perception and experience of the exercise activity.

The primary exercise activity at Akaciegården is the bike-centric manuped, because it allows residents to exercise unassistedly without risk of hurting themselves, and to their individual ability. The goal of this Ph.D. dissertation has been to use VR technology to augment the manuped exercise, to raise motivation to exercise with residents. Literature proposes that nature exposure is therapeutic and can be a rehabilitation factor by itself. Many nursing home residents are not physical or cognitively able to leave the nursing home without assistance, and are predominantly homebound to urban surroundings. The augmentation was therefore chosen to give residents a recreational bike ride virtual nature, from a choice of several virtual nature-based environments. Studies suggest that the augmentation has had a positive effect on intrinsic motivation to exercise, through noticeably increasing interest and enjoyment of the manuped activity. The project has been both VR software and hardware oriented. One study, for instance, tested the effect on residents exercise experience from increasing the immersive system properties of the augmentation, through an Oculus Rift. In other studies, the actual content of the VR experience and its role in exercise motivation has been addressed. Nursing home residents are an incredibly unique user group, and development for residents needs very different approaches than it is the case for most other users. The crux of the project lies in the gathering of the technology, the unique user experience approach, and motivation to exercise.

DANSK RESUME

Verdensbefolkningen bliver ældre. Som vores alder stiger, begynder vores krop og sind at miste noget af sin potens, indtil et punkt hvor vi mister vores uafhængighed, hvilket betyder evnen til at tage vare på os selv uden assistance. Disse alderdomssymptomer er delvis en funktion af vores livsstil, og jævnlig motion er i stand til at forebygge fysisk eller kognitivt forfald. For mange ældre er plejehjemslivet det, der følger mistet uafhængighed. At blive plejehjemsbeboer er et tegn på at ens funktionelle egenskaber nu har nået et nyt lavpunkt. Plejehjem er opmærksomme på denne realitet, og tilbyder fysioterapi som fysisk rehabilitering for beboere. Men alderdom gør mange ting sværere – motion inklusiv. På plejehjemmet Akaciegården på Frederiksberg, DK, har beboere vist en mangel på incitament til at motionere, på trods af kendskab til de funktionelle fordele, og et glimrende forhold til fysioterapeuterne. I denne afhandling blev det fundet, at manglen på motivation til at motionere, stammer fra en manglende glæde ved den primære motionsform. Virtual reality (VR) teknologi har potentiale til at udvide fysioterapeutiske aktiviteter, ved at tilføje alternative former for feedback til aktiviteterne, via interaktiv teknologisk mediering, og derved ændre brugerens opfattelse og oplevelse af motionsaktiviteten.

Den primære motionsaktivitet på Akaciegården er den cykel-orienterede manuped, fordi den tillader beboerne at motionere uassisteret, uden risiko for at slå sig, og udfra deres personlige ydeevne. Målet for denne Ph.D afhandling har været at bruge VR teknologi til at augmentere manuped motionen, og forøge motivationen hos for beboerne til at motionere. Litteraturen foreslår at natur oplevelser er terapeutiske og i stand til at være en rehabiliterende faktor i sig selv. Mange plejehjemsbeboere er ikke fysisk eller psykisk i stand til at forlade plejehjemmet uden hjælp, og er hovedsageligt stavnsbundet til urbane omgivelser. Det blev derfor besluttet at augmentationen skulle tilbyde beboerne en rekreation ved cykelture i en virtuel natur, fra et udvalg af virtuelle naturmiljøer. Studierne antyder at augmentationen har haft en positiv effekt på intrinsisk motivation til at motionere, ved en bemærkelsesværdig forøgelse i interesse og fornøjelse ved manuped motionen. Projektet har været orienteret mod både software og hardware. I ét studie blev effekten af beboernes motionsoplevelse evalueret, i forbindelse med at hæve de "immersive" egenskaber ved agumentationen, gennem et Oculus Roft. I andre studier har det været indholdet af oplevelsen og dens rolle for motivation der har været adresseret. Plejehjemsbeboere er en helt unik brugergruppe, og udvikling til beboere kræver meget anderledes tilgange end for de fleste andre brugere. Spændingsfeltet i projektet ligger i samlingen af teknologi, den unikke tilgang til brugeroplevelsen, og motivation til at motionere.

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I would like to express a substantial gratitude towards my supervisors, main supervisor Professor Lise Busk Kofoed and co-supervisor, Professor Stefania Serafin. Both have been central corner stones in my affiliation with academia, and my development as a person. Both were among my first teachers when starting my B.Sc. degree in 2005. 10+ years later, they are still my teachers, only now guiding me to PhD degree. I will never forget both supervisors for their personal investment into the mere possibility of this project. My thanks go to both for believing in me from the beginning, for guidance throughout the process, and for providing optimism when things were hard.

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But foremost, to my wife Mette and my kids Molly and Bastian. Thank you for everything. I look forward to every day we are going to spend together.

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CHAPTER 1. INTRODUCTION

"I am a sensually curious, and perceptually guided being"

Contemplating the years educating myself in the uses of media technology, several acknowledgements stroke me. The one thing that tied it all together, and has guided most of my central interests throughout my life, can be explained by the quote above.

Since childhood, experiences that would blast my senses with stimuli would form a focal point for my leisure activities. During remarkable experiences through hearing or seeing (or in combination), I would 'zone out' of social existence, and often only return when my parents needed my attention. When delivered by technology, high-impact sensory (e.g. high fidelity audio or impressive CG visualizations) and multisensory (multichannel audio with visuals) presentations would completely absorb my mind and attention, by the sheer perceptually overwhelming nature of their presentation. Or they would be experiences that would let my imagination run free, and effectively allow my mind to take me to another, imaginary place. On such occasions (if good enough), I would find myself at peace, while very excited at the same time.

As a child (and growing up), I was a raving introvert. The real world was scary to me, often being too intense, too fast or too complicated to understand. I was also very sensitive, and too emotional to handle adversity very well. As such, I would always prefer to stay at a safe distance from many things (especially social interaction) to a position where I would have time to observe, and try to understand things happening around me. Ironically, the things I found scary and removed myself from in real life were often the things that fascinated me intensely, and often became things I longed for. Technologically mediated experiences (music, movies, games, etc.) thus became a paramount part of my life. They allowed me to 1) observe situations that I would not allow myself to engage first hand, from the physical distance of my private residence, while still making me to feel like I was close to the event. 2) To access them by personal choice and in my own time, which was so different from real life. 3) Intense displays of impressions that would fill my general need for robust, perceptual stimulation. 4) And the emotional experiences from the content and artistry of music, movies or games, typically by their moods and impressions, and often as inspiration for my mind to wander.

Jumping in time to the present, some things have changed, and others have remained. I've learned to overcome many of the challenges related to my fundamentally introvert nature, but my affection for technologically mediated experiences remains. Meanwhile, as a consequence of studying the field for almost a decade, as a student and later an employee at the Medialogy education in Aalborg

University Copenhagen, my appreciation of media technologies has changed. Medialogy teaches the knowledge of technological media, from the perspectives of computer science, media psychology, and sociology. The graduated medialogist is ample in the discipline of using media technology to communicate purposefully a specific experience that hits the psychology (e.g. perception) of a specific user demographic. From a developer's point of view, media technology unveiled itself as a tool, more than a mystery black box. I grew to highly respect the complexities inherent to mastering different technologies. They are instruments, by their unique capabilities, characteristics, and limitations. Their effect on the overall orchestra adds certain dynamics to the overall harmony, to deliver an ultimate expression with the end-recipient. By that final step, the end user, complexity is added once more, from the undeniable realization that user experiences are perceived differently, depending on its particular individuality and characteristics.

The complex nature of the user group has never been as real in my academic career, than in this PhD project.

1.1. ROAD TO REHABILITATION IN THE VIRTUAL DOMAIN

During my studies at the Medialogy education at Aalborg University Copenhagen, I developed an affinity for the theoretical perspectives of multisensory perception and cognition. In no other research area did I find as much potential for exploring this, as with *immersive virtual reality* (IVR) experiences in *virtual environments* (VEs). It was intriguing to me how mediated multisensory stimuli and behavioral tracking could combine to form perceptual illusions of place and actions. Illusions that are able to persuade a user to feel as if placed elsewhere than their physical location in real life. I also loved how working with IVR, required understanding the individual characteristics related to each sensory modality, and the complexity of their combination, to use them correctly. My childhood mind wanderings were suddenly coming closer to being possible in something less imaginative, and more resembling a real life experience.

The two last projects I did during the masters program worked within the virtual domain. The first was a project with some fellow students, which was the first experience with *augmented reality* (AR), and became an eye-opener of the potential of AR for rehabilitation. Azuma, et al. describe AR as the combination and alignment of real and virtual objects in a real environment, running interactively in real time [**1**]. In the project, we created an artificial, augmented body part; an extra limb, in the form of virtual butterfly wings. The project tested the possibility of the sense of "pseudo proprioception", a self-coined term indicating a convincing proprioceptive sensation of an artificial/virtual limb. By a combination of a real mirror and a virtual mirror (a projection displaying the augmentation), users would see a reflection of themselves from behind. On their back, they see a set of large, beautiful butterfly wings. Through EEG, users would be able to flap the butterfly wings by muscles activation of their back shoulder. The real-time alignment of the behavior between user and wings connected the virtual to the real, through visual and proprioceptive stimuli conjunction. User responses suggested that pseudo-proprioception had been obtained, to a high degree during trials. Many participants were surprised and some even shocked about the effectiveness of the illusion.

Figure 1: The visual/proprioceptive illusion of a virtual limb, granting the participants butterfly wings, which they could move fairly accurately with gradual shoulder muscle tension.

After the project had ended, the system was taken to a high-level physical therapy clinic in Copenhagen, for the project's potential in physical therapy and rehabilitation. It was during this interview, and when seeing the enthusiasm and excitement from the therapists, where I realized the potential of media technology combined with exercise, and how using augmentations wound amplify or alter the perception of body activities and movements, and be extended to something completely different with AR and VR influences.

The second project was my master thesis, made under the free equipment usage and supervision of the Multisensory Experience Lab, at Aalborg University Copenhagen. The project did not focus on rehabilitation, but on multisensory perception in the virtual domain, by a study of methods for measuring the sense of presence from a cognitive psychology perspective. The project tested this using a nonvisual experience of a circus tightrope act, having participants walking blindfolded on an audiohaptic representation of a wooden plank under the ceiling of an audience-packed circus tent (soundscape). The project was a great theoretical exercise in multisensory displays and psychology, but also felt slightly detached from real world application.

1.1. UNDERSTANDING THE PROJECT

The initiating idea behind the Ph.D. project built on the hypotheses that users of monotonous indoor exercise routines would consider it repetitive and uninteresting. A coexisting hypothesis was that the correct use of media technology, for instance in the form of interactive and immersive VEs, could provide an additional ‘layer’ on top of the exercise, and decrease boredom. Most people have the impression that exercise benefits our wellbeing and health, but not all individuals have a natural affection for exercising. In this context, interactive and immersive VEs could raise the motivation to exercise.

During the formation of the project direction, it was proposed that while such intervention might be relevant for most user groups, the demographic of older adults might be academically interesting, and very pertinent in a societal context. The academic interest stems from the limited body of work in the field of older adults and immersive VR. The relevance in the social context is explained in more detail in Chapter 2, but relates to how society (in this case, the Danish) allocate considerable resources to the expenditures of the daily care of the older adult demographic [**2**].

At the time of the project’s inception, commercial exercise products were slowly becoming available, offering media to accompany indoor exercise, often with the proclamation of ‘increasing motivation and ‘enhancing’ the experience'. The method commonly used was by prerecorded video footage, typically of the outdoor version of an indoor exercise activity (walking, running, biking, etc.). Italian fitness company TechnoGym , for instance, offer such for a selection of their fitness center biking products, via a small pre-installed monitor. The speed of the footage is scaled, corresponding to the speed of the user on the fitness bike.

While similar in nature, the objective for this project was the desire to use real-time, computer generated VEs to create the world and content of the displayed augmentation, instead of prerecorded footage - for the following reasons.

To allow an ongoing presentation no matter user input. In the TechnoGym solution, the scaling of the speed means that if the user stops pedaling, the footage stops. The result is a ‘real world put on pause’. Birds hang in the air, and people stand motionless by the road. When biking at slow speeds, the world representation (footage) would display an environment moving in slow motion. Conversely, when biking at high speeds, the world representation would look like a VCR on fast-forward. For the same reason, audio is not a part of the TechnoGym solution. With the Virtual Active product, the DVD video would run in a single speed, no matter the exercise input from the user. This allowed audio, but at the expense of interaction.

To allow advanced interaction designs. Common for the Virtual Active and TechnoGym products, the recorded footage allowed limited to no interaction with the displayed environment, aside from the speed gradient in the TechnoGym installation. With real-time computer-generated VEs the freedom to design user interaction, allow user choices and implement gamification elements is almost limitless. Examples are navigation inside the environment, visual orientation, behavior of in-world objects (movement, interactive characteristics), interaction with said objects, etc.

To be able to design and control exact content and interaction designs. A large part of the project relates to identifying exact user needs and promote user experiences that fit specific user preferences. While prerecorded footage has the advantage of ecological, photorealistic visuals (while running correct speeds), it is limited in content by the availability of the footage, or the resources to produce new content. Contemporary VE creation software (such as Unity3d, Unreal 4, or CryEngine) allows custom content creation without the many barriers of prerecording footage (e.g. travel expenses, weather conditions, recording equipment, staff expenses, removing unwanted in-scene elements, legal permits, or post-production).

To be able to control the technological display. The control of the VE display methods plays a fundamental part of the user experience, from the perspectives of the immersive properties of the system (as defined by Slater [**3**]). This is something that will be explained in greater detail later in the dissertation, but fundamentally relates to the degree, in which the senses are convinced that the user is actually situated inside the VE, and whether the events happening inside the VE feels like they are actually taking place [**3**]. The impact of this is related to all considerations listed above, from the perspective of the user experience of the interaction possibilities, and the user perception of the custom built virtual world. Methods for enhancing the immersive system properties relate to its ability to display stimuli to all senses, and its ability to represent and react to user actions. Such displays are predominantly possible with computer-generated real-time virtual worlds.

1.1.1. THE HARD REALIZATION OF THE PROJECT PREMISES

Personally, it was a privilege to be allowed to return to the idea of augmenting exercise and physical therapy, especially for a Ph.D. project proposed to explore the dynamics of the nursing home resident user group, exercise motivation and interactive experiences in IVR. Exercise motivation was a new field for me, however, and older adult nursing home users were considered exotic as a user group. While research on immersive VR has been growing as a field over the previous decades, documentation on its merits with older adult users seems almost illusive. Literature highlights the benefits from exercise for physiological and cognitive health with technological augmentation displays [**4**] [**5**] [**6**] [**7**] [**8**] [**9**] and how games for exercise are able to support motivation purposes [**10**] [**11**] [**12**]. However, literature on game designs for elderly [**13**] or exercise game considerations for elderly [**14**] [**15**] was much more sparse. No previous studies were found using highly immersive VR with elderly users or using exercise media technology for nursing home residents.

To proceed was to engage a nursing home, and start developing a background by empirical studies. The preconceived method of defining user needs was to explore the spectrum of exercise activities used by nursing homes, analyze user preferences, challenges, potential lacks in motivation, and find the causes. It was expected to be a long process of observing, interviewing and collecting data on several parameters discovered during interviews. And it was projected to be an equally long process, to consider and choose among countless possibilities for immersive VR augmentations, to different exercise methods, according to various user preferences, etc. And which interaction and gamification designs would be needed, which additional interfaces would have to be built, etc. From the literature on 'elderly' or 'older adults', it all seemed possible.

I reached out to a nursing home called Akaciegården, in the Frederiksberg region of Copenhagen, and arranged a project initiating visit. That day is still a fresh memory, as it was the first step in a realization process that changed the whole direction of the project. After a meeting with the superintendent, I was approved and allowed to join the lead physical therapist in training sessions at the clinic. During a week spent at the clinic, I started as a non-participant observer, noting the residents' exercise routines, impressions on physical performance, exercise devices used, the different social roles, etc. Over the course of the week, I gradually transitioned into a participating observer. I was able to participate in casual conversations with residents and staff, to initialize myself as a person in context, and get personally familiar interacting socially with residents. I was also able to perform semi-structured interviews with a handful of residents while exercising, about their impressions exercise, what they could think of to improve the exercises, and what they thought about the idea of an additional layer for instance through immersive technologies.

When I left after that week, it was clear that the project needed rediscovery in some crucial areas. The course of the week at the physical therapy had fundamentally changed my perception and understanding of the contextual circumstances of the project, concerning the user-oriented requirements needed to proceed. During my conversations with residents, it had become clear that most of the things I initially believed to be possible were not, and that the fundamental premises I had originally expected were very different, as illustrated in the paragraphs below.

Exercise activity types reflected the general physical performance level. Only two exercise types were generally utilized. The first was the parallel walking bars, for standing and walking exercises, performed with the assistance of the physical therapist. The second was a chair-based biking device for arms and feet, called a manuped (Figure 2). The pedaling action was performed with pedals for the feet, and handlebars for the arms. The low physical strength of residents meant that many were barely able to complete the simple actions required by the exercises.

Figure 2 The manuped exercsie 'bike'

General physical condition for attending residents was lower than expected. None were unable to walk unassistedly, only a few barely able to walk with a ‘walker’ (a stand on which to lean for balance and strength relief), and many were in wheelchairs, and only able to e.g. stand up in short bursts, including assistance.

Physical exercise performance reflected the physical condition. Exercises on the manuped lasted 30-45 minutes, with extremely low levels of exertion, and with time spent taking breaks. For personal reference, I tried the standard manuped exercise

(500 rounds on the pedals), which could easily be completed in 6-7 minutes (for an adult with an average physique, keeping a comfortable pace). Exercise duration for the walking bar was significantly shorter, lasting 5-10 minutes. Most time was spent on breaks between trials, as the exercise procedure was quite painful for most residents, and therefore demanding both physically and mentally.

Communication abilities of residents, based on experience during conversations and interviews, showed to be challenging from a qualitative data perspective. Only a few were able to uphold a reasonable conversation. Others were almost unable to conduct discussion, due to a variance of inabilities on the cognitive and physical level (physical, as in lack of energy to keep focus or talk). Residents' cognitive challenges showed, as for instance in relation to dementia, making residents repeat themselves with 5-20 minutes intervals. They would often restart a previously told story, as if never told before. Besides, some would change topic without warning, despite being in the middle of a particular conversation topic. In other cases, it seemed like some residents simply tried to redirect the conversation to their topics of preference. They would answer a question quickly, and just as soon change the subject to their personal agenda - which in all likelihood had already been addressed 5-20 minutes before.

Conceptualization abilities. This area seemed related to many of the communication abilities challenges, about the cognitive or memory oriented limitations. When asked for personal opinions, concerning possible changes or improvements to their exercise routine, most would not be able to suggest anything.

When explained how it would be possible to be able to see something on a screen, while biking, which could relate to their efforts on the bike, they did not understand. When being told that they would (for instance) be able to see another place on a screen, through which they could drive, they did not understand. When asked what type of environment (or surroundings) they could imagine themselves enjoying a bike ride through, most would respond that they were not able to bike anymore. It did not help to repeat or rephrase the question. Most confusing were questions asking residents to imagine seeing a lovely landscape on a screen which would move forward while they were biking on the manuped as if they were biking through it themselves. Upon given such question, some would not reply, but paused for a moment, and only start talking about something else. Others would look at me, and try to search for something in my facial expression, that they might have missed, to understand what I was talking about. The main thing to take away from this experience was that I would not be able to rely on resident participants to imagine new concepts, or give advice to possible improvements without seeing to trying something very relatable to the topic in question.

On a positive note, it was also possible to conclude that most residents had positive memories of biking at a younger age. Biking was by many recollected as a past leisure activity, for instance, bike rides around the village, town or city in which they lived, or to take the bike to the countryside for nature experiences.

From the initial conversations with residents, and from non-participating observation, it was indeed possible to obtain particular insights to the circumstances and potential problems related to the Ph.D. project agenda. From observations, the most frequently used exercise activity was the manuped. Either, residents were exclusively using the manuped for exercise, or they were using it as a warm-up supplement to trials on the parallel walking bars. Residents could operate the manuped without the need for further assistance from the physical therapist, due to the safe nature of the activity. A regular chair with armrests demands no assistive support from the physical therapist, as risks related to balance or strength was non-present. From a staff resource perspective, this allowed the physical therapist to service other residents in the meantime, making the manuped a very productive activity in context.

However, the manuped also represented a social void. When active, residents would sit alone, facing either a window to a yard or a wall (there were two manuped type devices in the clinic), with their backs facing the rest of the room, resulting in nearly no social contact to anyone else in the chamber. From the conversations with residents concerning the manuped, it was suggested by many that the act of pedaling the device was not exactly exciting. But most focused on the positive sides of the matter, by the physical benefits it would eventually provide, and how in many aspects, sitting by the manuped was no worse than sitting in the hallway on their room floor. Negatives were boredom and physical pain, which could sometimes challenge the incentive to attend the physical therapy sessions when seated in the room and making the decision to head down. This suggestion was supported by conversations with the physical therapist, highlighting a problem of getting residents into a regular exercising routine. There were a few issues, but one of the main was a sensation that residents seemed to try and avoid regular attendance. This presumably related to the physical challenges residents would be facing, and perhaps due to the lack of time and resources to make their experience ‘eventful,' as a consequence of the suboptimal therapist/resident ratio. From observations, I could agree to this. Residents and the physical therapist got along very well, and it seemed that the residents very much enjoyed the company of the physical therapist. However, it also appeared to be the lack of sufficient attention possible for each resident was counterproductive in the sense that residents, who were not given attention for a while, projected the sensation of being abandoned for another peer.

1.1.2. INTERACTION COMPLEXITY AND PHYSICAL DEMANDS

Based on the experiences listed in the previous section, nursing home residents are more mentally and physically challenged than presumed from the project’s inception. Physically, the residents (in general) were substantially below the performance levels found in literature discussing exergaming for elderly. Nursing home residents, from the experienced, just described, are thus not to be blindly considered a reflection of the research categories ‘elderly’ or ‘older adults’, but a unique class in itself. Besides, the majority of residents I was able to meet and talk to, were challenging to communicate with, due to low energy, short memory and attention span, and a desire to talk about things unrelated to my desired context of the conversation. Residents were hesitant to go into detail about negative aspects to the exercise, and were rarely able to rationalize or imagine concepts not clearly in front of them. They had no conception of media technological possibilities, which made gathering insights for a future pilot study implementation both challenging and shallow, compared to what I had initially hoped.

Issues related to a lack of enjoyment of exercising did present themselves during observations, and seemed to relate to the physical challenges faced my many residents (predominantly strength limitations or arthritis related issues), and possibly also to a lack of meaningful experiences while exercising. From a discussion with the lead physical therapist at Akaciegården, it was agreed that the manuped should be the platform for future implementations and studies. The therapist also acknowledged that motivation to exercise for many residents seemed weak. From the perspective of the physical therapist, many residents were attending the sessions partly because they were bound to a promise-based engagement between them and the therapist. While the therapist agreed that it was a suboptimal method to ‘force’ residents to exercise, based on this interpersonal and emotional connection, it was decided to be a necessary evil. Increasing the attendance frequency of residents was believed to be of high priority. It was, however, the therapist’s impression that those residents were happy to be there once arrived.

Based on the newfound experience of the residents, a positive experience was how the initiating project hypotheses were not disproven. In all likelihood, nursing home resident users of monotonous indoor exercise routines (in this case the manuped) did, in fact, seem to consider a less than positive experience in some respects, and at the nursing home, there appears to be a recognized state of discouragement to exercise among residents. The fact that residents were unable to relate to augmenting exercise, or the role of media technology and immersive displays, means that the possibility of positive effects from such setup was not disproven.

Meanwhile, the defining experience of nursing home resident characteristics made it apparent how a better understanding of the capabilities and limits of the resident user group was crucial. Concerning physical and cognitive abilities, residents would have to be able to both understand and perform the tasks inherent to the exercise augmentation. At this point, it was not clear where that balance would be found, but clear that residents seemed to need a much simpler experience, compared to the initial expectations. At the same time, it remained unsupported whether residents were demotivated to exercise, which parameters of the exercise experience could improve motivation and how it could be achieved.

To approach an answer to these questions, I arranged a focus group session with eight residents (appointed by the lead physical therapist). The purpose of the session was to get more experience interacting with residents and to observe and possibly get insights to behavioral patterns, physical ability, interface interaction skills and overall preferences, during a play session with a Nintendo Wii. The Wii has been used with positive results in several studies related to promoting physical activity [**16**] and balance treatment [**17**] for elderly users. The game used was Wii Sports, which has a collection of small sports games which the user can practice using the Wii controllers (see Figure 3). Residents would have to complete two separate steps to bowl. The first step was to press a direction button for the horizontal aim angle; indicated by a huge arrow moving on screen with every button press. When the angle was chosen, the second step was to hold a different button (simulating holding the ball), swing the controller and let go of the button. The only place in this sequence that required timing was the letting go of the button.

The focus group session led to the following conclusions:

a) Besides one, residents were practically unable to interact with the Nintendo Wii Sports Bowling gameplay. Remembering and understanding steps were hard, and the level of complexity in timing the button release was too high for the cognitive or motor-based deficiencies of most residents.

b) Residents who were unable to perform the required actions within the Wii Sports game experienced apparent personal defeat and embarrassment, instead of a personal encouragement to keep going or learn a new skill.

From an interaction design perspective, this could be a matter of practice. However, relying on gradual improvement of interaction skills seemed risky. The reactions of discomfort and embarrassment by residents unable to perform the interactions indicated that introducing equal interaction complexity to a manuped augmentation would probably result in a more destructive than constructive effect on motivation. The impression was that many residents might remove themselves from exercising, before being able to practice sufficiently to succeed.

Figure 3: Wii Sports Bowling. 1-4 illustrates the controller interaction scheme[1]

The presupposition from the initial week of observation that simplicity would likely be an essential delimitation for an interaction design was confirmed from the focus group session. It also led to the paradoxical realization that resident users seemed vulnerable to the wrong experiences, but should be considered unlikely to provide insights to their preferences before practically testing a system.

That concludes this little narrative of an introduction. The story is meant to share insights into the transition from comfort zone based expectations to uncharted territory, and towards the necessity for acclimatization and personal development as a researcher, to be able to lift the task. In this dissertation, the considerations, methods, and techniques will be proposed, for one solution to using virtual environments as the catalyst for increased intrinsic motivation to exercise for nursing home residents.

As previously described, the incentive to start the project was to explore the combination of older adults, immersive virtual reality and exercise motivation. As it is shown in the following chapter, the quantity of older adults in Denmark is increasing, and will continue dramatically over the next decades [**2**]. There is a need for keeping them as physically active and capable, and as independent as possible, to decrease expenses on society, and to increase the quality of life for the elderly

[1] http://www.wikihow.com/Bowl-an-Easy-Bowling-Strike-in-Wii-Sports

individual. Performing exercise becomes challenging with high age, and finding ways to make exercising seem more inviting can potentially prove a major factor to older adult demographic requirements for health care. This project is one of a hopefully large body of research, which will aim to explore how to affect older adults' exercise incentives positively. The method is through immersive virtual reality technology, and experiences of virtual environments as the attractive element used to augment an exercise, and thereby increase exercise motivation.

Throughout its duration, the project has been fortunate to continue its close access to the daily-living nursing home residents and their routines at Akaciegården. This has facilitated iterations of observation sessions, interviews, private visits and social interactions with residents and nursing home staff, for studies aiming to measure the effects on exercise motivation when implementing virtual technology based exercise augmentation. And it has also given insight into valuable considerations and necessary precautions, when working scientifically with this type of technological development, with this particular user group. The resulting understanding of what constitutes the nursing home life, residents' abilities, opinions and practices to daily physical exercise, has enabled the project to highlight a previously unexplored angle to of virtual technology for nursing home exercise activities and rehabilitation.

CHAPTER 2. BACKGROUND

The Danish population is increasing, it is getting older, and the average life expectancy is increasing. According to the *Statistical Yearbook 2015* from Statistics Denmark [**2**], the period from 1980 to 2015 has seen a general population increase from 5.12 million to 5.66 million, the average age has increased by 4.2 years, the population aged 80 or higher has grown by 68 %, and citizens' aged 100 or higher rose by 647 %. In 2014, the number of dwellings for elderly people was approximately 40.000, for nursing homes purposes. Resident distributions were 11% aged 80-84, 21% aged 85-89 and 40% aged 90+. The need for permanent help increases with age, with 31% being in need of permanent help at the age of 80-84, 55% need at the age of 85-89, and 91% by the age of 90 years and up. Nursing home related expenses for the State is an estimated annual cost of kr. 12.49 billion (€1.67 billion) [**2**].

The deceleration of physical ability affects health and everyday life quality [**18**] [**19**]. Older adults most often transition from private residences to nursing home residency due to incapacities or limitations to cognitive or physical ability related to old age. Schwartz describes the decline of functional status thresholds, at various points along a decreasing slope, signifying the functional ability. [**20**]. With increasing age, an individual loses a series of physiological components, such as strength, endurance, flexibility, balance and coordination (which Schwartz shortens to the term *vigor*), in a non-linear fashion such as indicated in Figure 4.

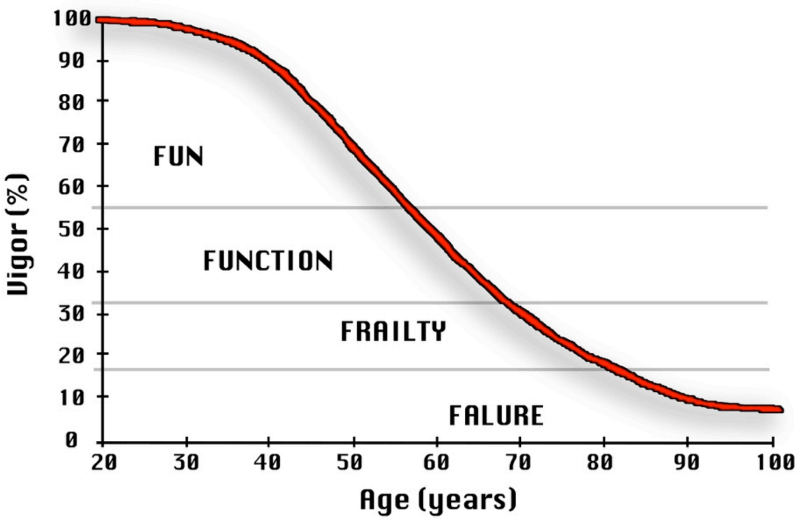

*Figure 4 - Loss of functional ability following age. Adaptation from Schwartz [**20**]*

Physical conditioning can counteract most deficiencies related to age. Part from the vigor in Figure 4, the frailty stage as a geriatric syndrome, represents cumulative declines such as impaired homeostasis (metabolism, acid-base balance, body temperature, glucose concentration, calcium levels, fluid volume, etc.), and reduced capacity to resist stress, resulting in unintended weight loss, exhaustion, weakness, slow gait speed, and low physical activity [**21**]. Physical activity does not play a predictive role in the degree of frailty, but should be considered one of the recommendations to avoid it. It protects against frailty components such as sarcopenia (loss of skeletal muscle mass following high age), functional impairments, cognitive performance and depression [**22**]. Frailty components in combination can create different negative loops. An idle lifestyle is a risk factor for muscle weakness. It results in an overall reduction in activity level, which affords losing muscle mass and strength (sarcopenia) [**22**] [**23**]. And while decreases in motor skills often have relation to cognitive disabilities (from advanced age), cognitive decline can conversely be directly linked to increases in physical inactivity or immobility [**14**]. Emerging physical decline can lead to e.g. falls and injury, resulting in increasing immobility. Immobility over longer periods affects cognitive performance, which in turn can prevent the foundation for reinstating increases in physical performance. This spiral of decreases daily function, and is potentially accelerated as ‘vigor’ (Figure 4) decreases, and therefore often results in a final, overall degradation of life quality [**14**] [**22**]. Specifically oriented physical activity (exercise) is the central approach to treat sarcopenia and slow down the age related declines, e.g. of muscle mass and muscle strength [**23**]. The expression *physical activity* should be understood as movement involving muscle contraction. This includes daily activities such as housework, walking, climbing stairs, etc. *Exercise* is to be understood as planned physical activity, from the intention of acquiring increased fitness or other health benefits [**22**].

At Danish nursing homes, physical exercise is, therefore, a priority. Having residents exercise, and having them be the most independent they can be, is a priority of life quality, as well from a societal resources perspective. The distribution of age groups in Danish nursing homes, and the related need for permanent help, listed at the beginning of this chapter, indicates the demand for nursing home care requirements. 2015 is seeing the lowest birth rate in Denmark in 30 years. Besides the future perspectives of a limited workforce in 29+ years, it also implies that Denmark is currently entering the lowest workforce resource in 30 years, to financially support (for instance) the care and healthcare of the highest number of inactive, nonworking older adult citizens in Danish history. According to [**2**], the result is an expected *dependency ratio* in 2030 of 1.06; meaning that for every 100 economically active and working individuals in Denmark, 106 persons will need support in 2030. The longer elderly citizens, for instance, nursing home residents, can live or function to the fullest of their independence level, the more resources can be allocated to those who cannot.

2.1. NURSING HOME PHYSICAL THERAPY

At Akaciegården nursing home in Frederiksberg, everyday care is built around an ideology called Project Life Tree (Danish: "Projekt Livstræ"), in which physical exercise is am an essential priority. The idea behind Project Life Tree was to promote physical therapy with the individual resident, to heighten everyday life quality. The idea was for each resident to have personal, functional goal for regular exercise, to retain (or re-achieve lost) daily life function, which had high priority for the resident, such as being able to lift a wine glass unassistedly. Over time, the Project Life Tree initiative has unfortunately gone to the background of everyday focus at Akaciegården, due to limited staff resources. But the attitude towards the importance of regular exercise remains a priority at the nursing home.

Akaciegården has 100 residents, and all are free to exercise if personally desired. Physical therapists are available four days a week in a designated clinic. On open days, the clinic is accessible two times a day (morning and afternoon), for respectively 2.5 hours. Residents can enter the clinic as they please during open hours. Some residents are able to travel to the clinic by themselves (wheelchairs or with 'walkers'), while others need assistance from care personnel to arrive at the clinic. All residents who join the clinic receive an individual program from the physical therapists. It is often based on specific and problematic physical issues, but the progression and development of the exercises difficulties and durations, are appropriated based on the physical, and mental state of the resident. The program is explicitly discussed and agreed upon by both parties. Emotion, lack of previous experience, fear of pain, fear of unknown procedures, etc. have shown to be among reasons why therapists sometimes start very cautiously. Going forward, they continuously evaluate the exercise-oriented requirement for each resident. Empathy and a professional compass for the physical and mental state of the residents, is a very valuable tool for the therapist. From the time spent at the clinic, they practice their profession being attentive, kind, and socially engaging. This creates trust between resident and therapist, and allows therapists the authority to dictate the exercise level, and push the residents to perform the necessary intensities, despite body pain and mental barriers which would otherwise prevent them from pushing appropriate physical limits.

Over the course of this project, the average participation in the clinic is approximately 10-15 residents in the morning, and 6-10 in the afternoon, depending on the weekday and activity schedule of the nursing home calendar. Many residents require individual sessions, for instance in the parallel walking bar. Resources during opening hours, therefore, need to be spent efficiently. Exercise routines that do not require personal assistance are therefore imperative, in the resource management of the therapy clinic. As previously highlighted, the manuped (Figure 2) is a device that has sufficient inherent safety in use, to allow residents unassisted exercise sessions. As most exercise bikes, the manuped gives the option of changing resistance in the pedals, to adjust the exertion level for the individual. Different from a regular exercise bike, the manuped activates both arms and legs, in various pedaling frequencies, for a non-static overall motion dynamic. As also described, interviews about the exercise experience showed that many residents at Akaciegården choose not to partake in physical therapy, despite being aware of the physical benefits related to regular exercise routines.

2.1.1. WHY RESIDENTS DISLIKE PHYSICAL THERAPY EXERCISE

A constant during the time spent at Akaciegården in relation to the project has been that residents attending the physical therapy sessions, really enjoy the company of the physical therapists, due to the social connection prioritized and cultivated by therapists towards residents (being caring, attentive and interested). Through countless observations over the years spent at Akaciegården, this has always been the situation. Residents seem invigorated during the time spent in the active, social company of the therapists. However, the majority of residents are not eligible for the personal exercise sessions (e.g. the parallel walking bar), primarily due to personnel resource limitations. For these residents, the active time spent in direct contact with therapists is minimal (typically a few minutes in total) and isolated to the greeting they get when entering the room, and the assistance they need when placed on a non-assisted exercise activity (such as the manuped).

It should be said that the quantity of residents simultaneously present in the clinic dictates this to a great extent. On occasion, the attendance is low, which increases social interaction time per resident during the visit. But during regular days, residents spend more time a) waiting in a queue (Figure 5), or b) alone by their appointed exercise device.

Subsequent interviews and casual conversation, concerned themselves with a) the general exercise experience, b) the manuped exercise experience and c) residents' reasons for inactivity or reluctance to keep exercise agreements. Responses showed that besides general body pain, 1) they don't like the activities themselves (including the manuped). 2) they might have been exercising regularly in the past, but lost motivation to return. 3) Exercising interferes with leisure-based activities at the nursing home or 4) (in their words) they are too lazy.

They don't like it. Despite being both exertion flexible and safe to use without assistance, the user experience of the manuped exercise was described as trivial and uninteresting. This is not surprising, as the activity consists of sitting alone, spatially static while facing one way (usually a wall due to the basic ergonomics of getting the residents in place) for 10-50 minutes (depending on the individual user performance level).

Figure 5 - Resident waiting in line to receive physical therapy, either from the manuped or assisted therapy

In this position, residents are left, chasing a fixed number of pedal rounds or fixed exercise duration. In interviews, residents have described the experience as trivial, boring and often physically painful. These tendencies are also found in rehabilitation literature [**24**] [**25**] [**26**]. Residents did attribute value to the proclaimed physical benefits of the manuped exercise, even though many did not feel the direct effect of the exercise in daily life[2].

They have been exercising but lost motivation. Illness regularly occurs among nursing home residents, and due to high age, recovery is a long process. General physical obstacles to resident's exercise, such as reduced muscle strength and body pain, which are improving with regular exercise routines, are pronounced when returning from periods of illness. Coupled with how many residents struggle with arthritis or coordination difficulties, returning to exercise can be extremely challenging. According to the physical therapists, many residents have given up on therapy, after several consecutive instances of illness and return to exercise. As explained earlier, immobility can quickly become a negative spiral, physically and mentally. Besides, the knowledge that the exercise investment is a long-term process that is very unstable, and losing it all when the cycle breaks, seems devastating for morale.

It interferes with leisure-based activities. Considering the immobility of many residents, it is a central part of the week at the nursing home, to have regular social events for leisure, monotony distraction and entertainment (movies, bingo, cards, etc.). These events are understandably a priority for most residents. Whereas exercise is a long-term, painful and often boring activity, the leisure activities have no physical requirements and provide short-term value. If the two activities clash, leisure activities have been the choice with extremely few exceptions.

They are too lazy. From the points just described, the lack of genuine desire to exercise can hardly be a surprise. Some residents explained how they would often sit in their room, and have time to exercise, know that it was the rational thing to do because of the necessity of the physical benefits, but ultimately choose not to go, primarily because of the pain, and how they disliked the exercise activities. When describing this situation, many residents displayed slight embarrassment and discomfort, in relation to honestly and explicitly admitting this position, showing nonverbally (uncomfortable body language, facial expressions) and verbally (rhetorically, tone of voice). These residents expressed a certain sadness about the situation; that they knew 'it was not okay,' that they should do join the physical therapy clinic more, that they needed the exercise (due to various physical complications), and ultimately feeling sorry about abandoning the agreement and promise to the very friendly therapists.

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[2] Neel Sass-Petersen and Maja Nørr-Larsen, who were physical therapists at Akaciegården during this dissertation, have approved all information and reflections on the therapy procedures described in this dissertation.

These insights indicate that the physical and mental challenges to exercise are substantial for many residents. Especially due to the high risk and instability in their physical conditioning process, which can make the long-term goals of exercising seem unobtainable. It also shows that pleasurable experiences with short-term value and routine distractions are in high demand and valuable. And it indicates that while the obstacles to conventional exercising can retain residents from engaging, there are dormant reasons why many would like more incentive to return to exercise.

2.2. EXERCISE AND MEDIA TECHNOLOGY

Games connected to, or constructed around physical activity and exercise are often placed under the category *exergaming*. Equal for most exergames are their focus to facilitate physical activity during gameplay [**27**] [**28**] [**29**] [**30**]. Exergames (at large) contextualizes physical activity by providing feedback to the real world actions, as events or activities from a mediated environment. From a technological perspective, this environment can be created from the rough categorization between custom built physical interfaces in the real world, typical user actions/interfaces augmented with virtual environments, or a combination of custom built interfaces and virtual environments. Common for all is that technology plays a guiding part for the activity schemes of the user actions. Exergame designs differ in orientation, as some implementations focus on supplementing a gameplay experience with exercise features (such as Konami's *Dance Dance Revolution* [**15**]), or by enhancing a conventional exercise experience with gameplay or game oriented features, such as the Kinect Trainer[3].

Research on exergaming outside the field of game design is not only or qualified by the game design challenges physical movement interaction design, but by their potential as therapeutic tools to societal issues. Examples are obesity therapy [**6**] [**12**] [**31**] [**32**], balance training [**27**] [**33**] [**34**], motor skill training (often related to post-stroke complications) [**30**] [**35**] [**36**] [**37**] [**38**], learning and training transfer [**30**] [**39**] [**40**], cognitive benefits [**41**] [**42**], and general exercise motivation [**12**] [**43**]. In these contexts, the technological mediation is less about promoting above-average physical ability, and more about exploring a potential for *rehabilitation*. Rehabilitation can be defined by the focus on *"the functional outcomes of pathologic processes and uses a variety of therapeutic interventions to restore function"* [**44**]. This can be initiated by developing either a specific set of skills or a support system, needed to therapeutically strengthen an individual's level of functioning [**45**]. Physical therapy rehabilitation specifically aims at the restoration of physical mobility and functionality. Geriatric rehabilitation is furthermore defined by the quantity of conditions at high age, which interact to produce disabilities [**44**], as it has also been described in the Introduction of this dissertation. However, a crucial part of geriatric physical therapy relies on exercise, as stressed

[3] http://www.fastcodesign.com/1671136/review-nike-kinect-is-the-perfect-exercise-game-with-a-fatal-flaw

by Guccione, et al. how "*Exercise may well be the most important tool a physical therapist has to positively affect function and increase physical activity toward optimal aging"* [**46**]. Rehabilitation activities in geriatric physical therapy and exercise, while not interchangeable, are therefore to be considered closely linked. Ordinated, physical therapy exercise, *is* rehabilitation, from the perspective of seeking increased fitness in relation to the constant struggle against e.g. the high pace muscle mass degeneration.

2.2.1. VR BASED REHABILITATION FOR ELDERLY

The Nintendo Wii has been given a lot of attention as a platform for physical activity and exercise engagement for older adults. Positive results have shown in relation to increased physical activity [**16**], balance treatment rehabilitation [**17**] [**47**] [**48**], and motor control rehabilitation for post-stroke patients [**49**]. Meanwhile, as previously described, the focus group testing the Wii at Akaciegården suggested quite negative effects. And in a study by Laver, et al. [**50**], the use of the Wii console was found inappropriate as a physical therapy instrument for hospitalized elderly patients. Participants preferred the conventional physical therapy, stating that they believed to get more therapeutic value from the traditional methods [**50**]. Crotty, et al. [**51**] showed that while the Wii could, in fact, be useful for certain types of mobility therapy (for hospitalized older adults), results highlighted the need for more knowledge concerning the particular engagement preferences of older patients.

VR outside of the Wii format has proven very capable in the rehabilitation of many of the aforementioned areas of therapy. It seems specifically utilized in motor control for stoke patients [**35**] [**36**] [**37**] [**40**] [**52**] [**53**], cognitive rehabilitation [**54**] [**55**] [**42**], and gait therapy [**56**] [**57**] [**58**]. Holden and Todorov [**59**] argue how VR can be a very 'practical' technology, by its ability to facilitate experiences comparable to real world situations for individuals who are otherwise prohibited from experiencing them in a real world context. With VR based rehabilitation, studies take advantage of VEs and virtual objects, to contextualize and augment real world therapy activities, and allow training of real world skills in the virtual domain. A virtual supermarket can thus aid cognitive rehabilitation by practicing keeping an overview of everyday tasks such as planning, time and money consumption, navigation, objects to buy, etc. [**54**]. A beach environment can provide real associations, and surfaces from which footstep sounds can increase walking speed, with participants undergoing gait rehabilitation [**56**]. A virtual arm can effortlessly be experienced in many different locations, and offers different circumstances and tasks for post-stroke motor skill training [**35**], or facilitate telerehabilitation [**60**]. And an exercise bike can be augmented by a virtual environment, for instance, to address motor control and fitness deficiencies with post stroke patients [**53**]. Holden and Todorov [**59**] describe how VEs can be built and also changed dynamically and inexpensively, compared to seeking those variations within real world facilities.

A valuable aspect of VR rehabilitation relates to the concordance of visual and proprioceptive information during activities [**14**]. Conceptually it is comparable to visual biofeedback [**61**], as the mapping of the exercise movements onto the VE feedback, connects the visual and proprioception feedback to support a participant's sense of ability. This sensation is argued to be particularly important for older adults [**14**]. Enhancing the feedback can be a necessary tool to promote the experience of exercise actions with physically or cognitively limited users' [**59**]. VR rehabilitation can thereby create a distracting layer, as a method to shift attention away from any exercise-related pain [**14**] [**62**] [**63**]. These potential benefits from VE augmentation may result in "*a shift from negative to positive thoughts about exercise*" [**14**] and introduce motivation factors to the exercise experience, otherwise unavailable with conventional therapy methods. IJsselsteijn, et al [**13**] argue that older adults are receptive to new technology, provided they understand the benefits of the technology, for their individual purposes [**13**].

Another interesting advantage of VR rehabilitation platforms compared to conventional therapy, relate to the ability to convey realistic, 'ecological' VE experiences [**64**] [**65**] [**66**], and appropriate them to fit specific user requirements, based on individual needs and abilities [**14**] [**59**] [**67**]. Through VR experiences, a nursing home resident would be able to experience locations and environment types that would be unfeasible to visit in real life. Traveling presents many obstacles for nursing home residents, such as complications related to physical deficiencies, or personal endangerment related to how cognitive deficiencies (e.g. dementia) can lead to problematic situations in public spaces. Many residents, therefore, need assistance to travel (also locally). However, VEs offer interaction under safe and controlled conditions [**59**]. A freedom of design can shape and grade VE content, behavior and purpose [**14**]. Nursing home residents would be able to visit public space replications in VR, but never have to be afraid of forgetting the way home, forgetting to take notice of traffic flow, etc.

In summary, transferring the advantages and features listed above to the context of nursing home residents seems logical. From the arguments listed above, VR augmentation of nursing home physical therapy should be a method of pairing two problematic situations into one solution, using the lack of ability to explore the world outside the nursing home to positively affect the lack of exercise motivation among residents. The decision to focus on the manuped exercise platform means that the VE rehabilitation could quickly orientate itself to a biking experience. Concerning the purpose and tasks inherent to such biking experience, the previously described inability of complex interaction with nursing home residents suggests that the experience should incorporate a minimalistic interaction design. It is also important to remember, that the exercise is the premier focus, as opposed to a more exergaming oriented approach.

Considering how many residents struggled with the manuped exercise, and how the exercise format occupies hands and feet, the enhancement of the experience must come from the content and overall presentation of the virtual environment augmentation.

2.3. RECREATIONAL EXPERIENCES IN VIRTUAL ENVIRONMENTS

Nature could be more important for humans than many give it credit for. Multiple studies highlight how experiencing natural environments can bring benefits to both psychological and physiological wellbeing. Exposure to nature has shown to produce relaxation [**68**] [**69**], increase positive mood, recover attention capacity and cognitive functions, as well as reduce stress [**64**], even when merely perceived through a window [**68**] [**70**]. It has also been found an inviting environment for physical activity (e.g. walking or running) [**69**]. Nature experiences are thus often referred to as *recreational*. These positive effects have shown to be directly opposed by urbanized environments exposure. Bratman et al. [**71**] highlight how urban environments are causing rumination, which is a negative cycle of self-referential thought on personal, distressing matters. Rumination induces increased risk of depression and mental illness, such as anxiety disorders [**71**]. Bratman, et al. showed that a 90-minute exposure to a natural environment eliminated negative symptoms caused by a similar duration of exposure to an urban environment [**71**].

Due to these recovery-oriented features, recreational nature environments are often referred to as *restorative* environments, when discussed in medical or specifically physiological terms [**72**] [**73**] [**74**]. The term is often used in identical fashion to the term *recreational*. However, the trend seems to be that the former used for medical or physiological findings [**72**] [**75**] [**74**], whereas the latter primarily refers to user experiences related to leisure activities, urban planning for nature environments, or tourism [**76**] [**77**] [**78**].

Recreational experiences for nursing home rehabilitation by VE augmentation for the manuped exercise seems interesting, from the arguments presented above. Human beings' affinity for leisure activities within recreational spaces can be seen from the attractiveness of beaches, parks, hikes, and other ventures into naturesque environments, for the sake of enjoyment and relaxation. Irvine et al. [**69**] supports this in a study on park visitor experiences and personally perceived benefits of urban green spaces. In addition to inducing relaxation and revitalization, the park environment also inspired physical exercise [**69**]. Common for many of these destinations is seemingly the ability to *be* in nature surrounding, no matter whether lying on a blanket or sitting on a bench, or engaging in physical activity. As such, nature exposure seems to be a reward in itself for many individuals. The same could be suspected to be true for homebound nursing home residents, especially due to the general lack of natural environment exposure. This puts an interesting twist to the expected interaction design of the augmentation. If the leisure experience is by far the most central part of the augmentation experience, it could be suggested that other interaction aspects of the augmentation could be limited to a minimum, without jeopardizing the VE rehabilitation purposes.

2.3.1. VIRTUAL ENVIRONMENT DESIGN FOR RESTORATIVE EXPERIENCES

Restorative effects by natural environment stimuli have been shown to be measurable after just 5 minutes of exposure, even when perceiving the exposure through a glass window [**79**]. Meanwhile, past studies on the restorative effects of real world recreational environments through technological mediation (pre-recorded CRT display [**80**] and real-time plasma display representations [**79**]) have shown mixed results. Depledge, et al. argue positively for a "*resurrection of interest in the design and study of high-fidelity, ambience-rich virtual environments*" [**64**]. The authors suggest that software toolkits and the graphics hardware (especially considering the contemporary power/cost ratio) is now ready to produce convincing recreational VEs. Authors also suggest that research field holds great potential to promote health and wellbeing for disabled or elderly individuals with homebound living conditions [**64**].

Unfortunately, many studies using recreational VEs (RVEs) for rehabilitation purposes mainly use the RVEs as ambiance for a primary therapeutic task [**81**] [**57**] [**60**]. Even studies where VEs designs are used as a central component in their methods [**29**] [**53**] [**66**] [**82**] [**83**], investigations into the underlying therapeutic effects of their designs are omitted, for instance, regarding the role of the RVE content. An example is a study by Wargnier, et al. [**84**] where high-fidelity VEs form the context for their post-fall syndrome VR rehabilitation platform. The authors highlighted results, which showed that aesthetics and context was an important motivational factor for the older adult participants [**84**]. The primary tasks for the post-fall therapy were to navigate a virtual trail and hit glowing objects placed on either side of the trail, controlled by real world motor behavior. Over the course of the study, four VEs were used; two recreational-based and two urban-based. They served no functional role, besides as an ambiance for the trail and navigation tasks. However, the older adult participants rejected the non-recreational VEs (an indoor corridor and an outdoor city), while happily accepting the two nature-based VEs (a forest and a park). The urban VEs were rejected for being too 'narrow' (corridor) and 'cold/unwelcoming' (city). Participants described the recreational VEs as satisfying and realistic [**84**]. Despite these participant reactions, Wargnier, et al. did not present further causal analysis on the impact or background of the user responses [**84**].

Depledge, et al. state that content is essential for the restorative experience, and that there is a current shortage of research going comprehensively into cues and clues, which trigger human interest or sense of wellbeing in nature environments [**64**]. What is available in literature seems to offer individual parts of a large puzzle. This affords difficult design and development conditions for RVE developers, who do not have urban design- or landscape architectural backgrounds.

In fact, to the knowledge of this author, no studies are yet available that present a comprehensive framework, identifying key considerations for recreational VE design in VR. Examples are more insights into which 'cues and clues' we pick up while in a recreational environment, or the design of effective and appropriate recreational content, e.g. in a set of categories (as also requested in [**64**]). Moreover, literature is lacking recommendations or guidelines on how to combine this content into a convincing whole, and methods of how to 'bridge' it all into the virtual domain.

2.3.2. FOUR COMPONENTS TO RECREATIONAL EXPERIENCES

However, as previously mentioned, parts of the puzzle can be found in discrete studies. On an overall level, Kaplan [**75**] proposes that the restorative aspects of nature settings can be understood from the perspective of *attention*. He proposes that attention is a mental resource, which needs periodical 'resting' from demanding influences of our surroundings, and that particular types of natural environment exposure can be these resources. This occurs for experiences that inherently deliver stimuli by four components.

1) *Being away* means removing an individual's attention from the concerns related to one's everyday living environments. The component needs to be understood more as a conceptual notion, than a spatial one. Being away relates primarily to an experience of 'attention displacement', rather than a physical transportation to a different spatial location.

2) *The extent* demands that the restorative environment contains rich and coherent stimuli, which in combination induces the sensation of a 'whole other world'. This "*must provide enough to see, experience, and think about so that it takes up a substantial portion of the available room in one's head"* [**75**]. An environment's *extent* is less dependent on size than on its ability to portray richness, coherence, and complexity. Kaplan highlights Japanese gardens as a good example of a small space, which excels in extreme richness of detail, within a governing philosophy of coherence. *Extent* should enable a 'connection' to the environment, by its ability to catch the attention of the observer. At the same time, it should facilitate effortless exploration of its content. Incoherence in its inherent architecture poses 'problematic' issues for cognitive problem-solving processes [**75**].

3) *Fascination* in nature settings is predominantly a 'soft' type of fascination. Kaplan's descriptions infer that the inherent qualifications of *extent* are linked to induction of fascination, but only when the extent of the environment is represented as a coherent 'whole'. If an environment represents an eclectic package of fascinating, but discrete content, the restorative effect is not obtainable. If (soft) fascination is obtained, it allows an effortless appreciation of the environmental features and opens for the possibility of thought and reflection. In nature settings, fascination can arise from aesthetically pleasing and naturesque objects. Kaplan highlights examples of soft fascination entities, like clouds, sunsets, snow patterns, motion of leaves in the wind, or wildlife [**75**]. Soft fascination can also be understood as an opposing extreme to 'hard' fascination. The latter relate to e.g. adrenaline-inducing experiences, which require *directed* attention, effort and focus on cognitive processes. Hard fascination situations require constant reinterpretation of the chain of events and possible reaction.

4) *Compatibility* refers to how an individual's purposes for being at a specific location, must fit within that environment characteristics, and provide the information needed, to fit the individual's purposes. If the environment is unable to facilitate purpose seamlessly, it requires cognitive problem solving, which removes the ability for *fascination*. [**75**].

2.3.3. RECREATIONAL VE CONTENT, FEATURES AND STRUCTURE

For the design of an RVE, Kaplan's four components provide a useful overview of the considerations necessary to 'orchestrate' a developer's understanding of a recreational experience. The missing are parts of the puzzle, which can be found, but are scattered in literature, from a variety of fields. Examples of puzzle piece categories are examples of specific content that promotes the restorative experience, the aesthetic representation of the RVE content and an approach to spatial management of content within the RVE (when starting the blank worksheet of a virtual area in its developmental infancy).

Regarding content, Depledge, et al. [**64**] highlight *forests visuals*, *outdoors environmental sounds* (birds, water and wind), *natural colors* (greens, blues and browns), and *air* movement, and water with particular importance [**64**]. In a study on the recreational aspects of a mountain environment hiking (path-based) experience, Dorwart, et al. [**76**] note how "*Whether hiking alone or with a group, each of the 33 participants noticed and photographed more nature-oriented details such as plants and wildlife than any other type of feature*" [**76**]. The authors propose a set of recreational themes found to define hikers experience. *Nature-oriented details* being the most important content theme, is primarily related to the appreciation of near trail flora, such as plants, 'a green carpets of vegetation,' wildlife, vast surrounding forest, rock-formations, and general composite combinations natural elements for close inspection inspire exploration. *Scenic* *values* are deemed second most important. Examples are large views and distant locations overview, high altitude vistas of trees and beautiful scenery, light and shade combinations, and 'natural elements' such as waterways and waterfalls. *Management influences* refer to man-made constructions along the trail, which served to compliment or support the overall hike experience and thus, the recreational experience. *Depreciative behavior* was litter, trash, broken objects, etc. [**64**].

Besides identifying the content types of an RVE, it is important to remember that RVEs are technologically manufactured environments. A real tree growing in nature will always look like a real tree, but stylistic or low-quality representations of natural objects are part of the development options for computer-generated designs. When simulating nature, a designer needs to be conscious of the aesthetic features that create a resemblance to real natural environments. A visually perfect representation of nature is often referred to by the term photorealism - an image so realistic that it is indistinguishable from a photograph [**85**]. However, complete simulated photorealism is very hard to achieve, especially in real time from a computational performance perspective [**85**]. Fortunately, photorealism, correct imagery and high levels of geometric detail have been found less important for *perceived* realism in VR, compared to considerations of reasonable behavior (of VE objects and content), high-quality textures, and rich surface detail [**72**] [**86**] [**86**]. These 'features' relate to the technical considerations of the RVE development, whereas more artistic, central design features found in the literature refer to realistic lighting, high image complexity, subtle shadows and the correct scaling of objects [**72**] [**86**] [**87**]. Being able to include all realism enhancing features in an RVE is unrealistic from a computational performance perspective [**85**]. Some features most often need to be prioritized. In the absence of a formal priority list for these 'features for perceived realism', it becomes a subjective aesthetic choice. Such can be guided by analysis of reference media representing desired content and features. Most defining RVE features depend on the desired portraiture of the environment. For instance, grey weather and dense fog entail little to no shadows and a very simple "realistic" lighting method. In this scenario, these features will therefore not occupy computational performance, which can be allocated to include features, for example, dynamic behavior of wildlife or other content, high-resolution textures or high image complexity in the proximity of the user. However, features can often be scaled to a suitable compromise, utilizing gradients of the complexity levels. A crude example could be including medium quality shadows and medium quality textures opposed to the exclusive inclusion of one in high quality. If both features are considered necessary, but computational resources are not sufficient to render both at high quality, the compromise might give the best overall expression for a realism perception. As previously mentioned, such decisions can be supported by reference material from real nature environments.

As previously mentioned, most developers without educated backgrounds as landscape architects or urban designers might need a simple set of guiding recommendations, to spatially frame and structure the placement of RVE content. This would induce control, and limit complete coincidental placement of content. Vinson [**88**] proposes to keep control of content management by a landmark typeset, to improve recognition of the VE locations and thereby increase the likelihood of successful navigation for VE visitors.

For this project, the landmark typeset seemed the most useful approach amongst those found in the literature to guide content placement. Besides, focusing on creating recognizable locations might aid residents to remember experiences with RVEs. Supposing an RVE augmentation would be successful in increasing motivation to exercise, residents who suffer from dementia might be challenged to remember such experiences. As the navigation guidelines from Vinson serve exactly the purpose of location recollection, the landmark typeset made sense. Within the framework, different landmark types serve individual purposes. *Paths* (such as streets, canals) are channels for movement, *edges* (fences, rivers, etc.) highlight boundaries, *districts* (neighborhoods) are distinct areas formed by boundaries, *nodes* (town square, public buildings, etc.) are focal points for travel, and *landmarks* (such as statues) are distinct and impenetrable objects [**88**]. Individual landmarks need detail variations such as height, shape, etc. to make them distinguishable [**88**].

Vinson recommends that landmarks should be man-made objects, as these are easily recognizable, compared to nature-based content. Nature-based is considered virtual objects, which represent the much of the VEs identity and ‘fullness.' However, such is not to be regarded as remarkable compared to landmarks, according to Vinson. If nature oriented landmark are necessary, Vinson recommends man-made items (roads, sheds or fences), but also landscape contours (hills, slopes or cliff faces) or water features (lakes, streams or rivers) [**88**]. Low vegetation, tress, rocks, etc. are not part of Vinson’s conceptual direction of recognizable entities, which begs the question of their role in a restorative-based design. Vinson recommends landmark placement to be managed from a top-down perspective. Such process is supported by an architectural approach to e.g. gaming level design, referring to a molecular diagram mapping as a method to overview spaces and the connections between them [**89**]. Totten appropriately recommends that spaces in the diagram be defined by their role as landmarks, identical to those adopted by Vinson [**88**] [**89**]. If the top-down perspective can be referred to as ‘macro’ perspective, the evaluation of the recreational experience needs to include a ‘micro’ perspective, bottom-up approach that places the designer into the user perspective of the RVE. Only from this point of view can the micro-managing of virtual content and objects, landmark scaling (etc.), and artistic restorative feature effects (lighting, shadow, image complexity, etc.) be evaluated. It is also from this bottom-up perspective that the fulfillment of the four components from Kaplan should be analyzed.

2.3.4. PERFORMANCE REQUIREMENTS, IMMERSION AND PRESENCE

The term ‘user perspective’ (concerning the bottom-up design approach) infers the possible points of orientation for a resident interacting with the RVE augmentation. In this relation, the design and development RVEs needs to account for its content placement, to make sure that it is visible if it plays a significant role, but also to remove any content that plays no important part in the user experience. This relates to both performance requirements and balance considerations for the RVE design and development. Roughly speaking, performance requirements are a function of the volume of content generation, graphics features, and display technology requirements. - And these parameters are often dependent on the immersive demands of an application.

Performance requirement considerations

RVE content aspects such as plants, wildlife, water, etc. and features such as rich surface detail and dynamic lighting are a direct method of obtaining richness and high image complexity in an RVE (e.g. to achieve a sensation of *extent* and subsequently *fascination*). However, high quality and quantity content and features mean increased requirements for computational power. Performance requirements increase very fast, following increasing volumes of content. Ambitious game development will always attempt to limit computational requirements wherever possible, while trying to obtain the highest perceived quality possible. Graphically, this can be done through various techniques such as backface culling, occlusion culling, limitations to quality and distance of dynamic lighting, general draw distance, control of transparent surface materials, etc. However, a simple approach is to remove all unnecessary content from a scene, and only show content that will be inside the user’s field of view at any time.

Certain game designs, with racing games being a good example, utilize a forward-looking camera orientation along a fixed path (the race track). It makes the control of meaningful content placement easy to map and adjust, for any given part of the user experience, as developers and designers will know exactly which content is shown when. This affords a transparent need for performance requirements, and an easier performance optimization workflow. Other interaction designs allowed free orientation. Under such circumstances, performance and optimization have reduced control, and the non-forward facing camera requires that more parts of the RVE should be given content treatment as fully designed and implemented parts of a map.

A forward-looking camera view on a large flat screen TV seems feasible for use with nursing home residents. This takes into consideration how studies have shown that the restorative effect is possible even through a window [**79**], that mediated restorative effects have been possible, even through a VHS taped RVE on a CRT screen [80], and how other scholars are currently working on mediating realistic restorative environments through flat screens, to bring restorative experiences to hospitalized patients and older adults [**64**] [**90**]. Interesting aspects of such mediation are if and why the VR augmentation can 'connect' residents to the virtual feedback, based on their real world actions, and how they perceive the RVE content. Literature seems to support that they might be able to establish the connection, as long as the therapeutic and interaction requirements are fitting and they can recognize and agree to the purpose of the augmentation. Flat screen TVs are recognizable as a technology for nursing home residents, and the interaction design of the augmented exercise would remain unchanged.

Meanwhile, if the ambition of the VR rehabilitation setup with the manuped is to facilitate the best possible sensation of natural environment exposure, a flat screen TV might not be sufficiently convincing. Head Mounted Displays (HMDs) offer stereoscopic visuals for a three-dimensional display, as well as orientation tracking which allows a user to orientate him/herself inside a VE. The addition of such display technology is referred to as immersive experience, which can increase the sense of presence inside a VE. This places a different requirement to the RVE design, concerning awareness on content and landmark placement, as orientation angles go from controlled (flat screen) to free (HMD). Besides that, it places different (higher) computational requirements on the system, as it has to render two screens (the HMD panels) at once, instead of one (flat screen).

Immersive system properties

There are many definitions of both terms. In this project, I have chosen to follow the definitions of Mel Slater, because I find his framework logical, and very useful in the context the RVE experience. Slater defines *immersion* as a property of the technology or system, which deliver multisensory displays of a virtual environment to the user [**3**]. An immersive VR (IVR) system should aim to deliver "*displays (in all sensory modalities) and tracking that preserves fidelity in relation to their real-world sensory modalities*" [**91**]. The immersive properties of an IVR system should ideally provide the foundation for a perceptual illusion of reality in the virtual domain. Optimally, IVR systems should consist of visual, auditory and haptic sensory displays. Position and orientation tracking plays a critical role for immersive system properties by supporting sensorimotor contingencies (SC) as a "*set of valid actions that are meaningful in terms of perception within the virtual environment depicted*" [**3**]. Slater proposes that as the immersive 'degree' of a system is difficult to quantify, immersive systems should be differentiated comparatively between each other. Specifically, if one system can simulate another system in VR, that system should have superior immersive properties [**3**]. For example, a HMD based system is able to simulate a monitor-based system, but not vise versa.

The perceptual illusions of presence - responding as if real

The sense of presence is often being described by the sensation of 'being there' in another spatial location (for example a VE), than the environment one is physically situated in [**92**] [**93**]. Common for most theoretical perspectives on presence, are their focus on how human beings can feel as if reality is what they perceive through technological mediation. Lombard and Ditton, for instance, define presence as "*the perceptual illusion of nonmediation*" [**94**]. It seems that the goal of presence research has long been to strive for a recipe for understanding the 'complete' illusion; a perceptual illusion so complete, that a user becomes completely unaware of his/her existence in the real world. Slater has come to believe, that while people are able capable of feeling the sensation presence in an immersive VR (IVE), it is not possible to a degree where the individual loses mental or physical attachment to their existence in the real world. Highly immersive VE systems are thus able to increase very convincing perceptual illusions of *place* and *plausibility*, to a sufficient degree where a user would as they would in the real world, hence Slaters 'respond-as-if-real' RIAR framework [**3**]. The *place* illusion refers to the illusion often referred to as 'being there' at another spatial location (despite being consciously aware that one is not). The *plausibility illusion* refers to when events in the virtual world feel or appear as if they are really occurring (despite being aware that they are not). The method of measuring presence has seen numerous variations between scholars, based on their respective different approaches to the phenomenon. The Slater-Usoh-Steed (SUS) questionnaire (introduced in 1994 [**95**] and later revised several times [**96**] [**97**]) has been widely adopted, and measures presence through self-report of respectively 3 or 6 items, each measured on a 1-7 semantic differential scale. Scores of 6 or 7 classify an item to represent a sense of presence.

2.3.5. THE MANUPED AUGMENTATION

From the perspectives just described, it seems that recreational nature experiences in the virtual domain are fitting for the purposes of the nursing home exercise augmentation. From literature on recreational experiences, the cardinal points to restorative effects of nature exposure come primarily by nature-oriented details and scenic values [**64**] [**76**], as well as features from both technological and artistic perspectives. The 'layout' of the RVE design should be based on a combination of a top-down and bottom-up process, depending on the design purposes, where landmark placement should be used to structure content, and guide residents' recognition of the RVE.

A consideration for the RVE augmentation is whether or not the user experience should allow free navigation, enabling residents to steer themselves around the RVE. Residents operate the conventional manuped with relative difficulty (limited strength, flexibility, and arthritis), and have both hands and feet occupied while exercising. Manual navigation control in the RVE while exercising (at least in a traditional steering wheel manner) seems unfeasible. Even if manual navigation was more accessible from the manuped ergonomy, it should be expected to introduce a high risk of complications. If residents would not steer as intended, such as a resident navigating off the trail into a tree, or falling off a cliff in the RVE. Fixing the situation, either by a restart or steering the resident ‘back on track’ would introduce an additional task for physical therapists, during opening hours of the clinic. It would thereby remove some of the strength of the manuped as an exercise device, which is its ability to provide independent exercise sessions for residents. Of course, it cannot be ruled out that residents would, in fact, be able to learn some variance of a non-hand, non-feet gesture-based navigation system. But due to the cognitive and motor skill limitations observed with residents, during the focus group trial with Wii Sports, it should be expected that residents will not be able to steer themselves properly around an RVE independently, let alone follow a path in an RVE. Navigation through the RVEs should be performed automatically in software.

Concerning the use of display, both types previously discussed earlier are interesting for further evaluation. The flat screen TV is attractive because it is unobtrusive, it is familiar to most residents, and it is possible to share the visuals with others present in the room at the same time. The HMD is interesting due to its stereoscopic rendering and orientation tracking. HMDs can provide very immersive experiences if used and run properly to avoid VR sickness [**98**] [**99**]. Methods to limit the risk of VR sickness are to minimize rotation speeds, ensure a (system-wise) high precision and low-latency tracking [**100**], and the highest frame rate rendering possible on the given HMD (probably approx. the 75 frames per second) [**99**]. Nevertheless, the flat screen TV will have an advantage as a familiar technology, unobtrusive in nature, and able to communicate the RVE experience to a surrounding audience. The flat screen TV is a valuable asset to introduce the augmentation unobtrusively as a concept onto the physical therapy culture.

Choosing display type has a potential impact on the RVE design approach. The HMD would potentially require more work in the design process than ‘simply’ developing for an (orientation-wise) fixed forward-facing VR camera, for each RVE location characteristics, by demanding attention to content and landmark placement by the possibility of free visual orientation. Computational requirements for an HMD are also more demanding, as content will be rendered twice. RVE designs appropriated for HMD usage should, however, be able to transition onto a flat screen display without additional optimization from a design and hardware requirement perspective (but not vice versa), so RVEs made for the project will thus be designed with an RVE in mind.

Based on the literature, it is unclear whether residents will respond positively to an HMD. It might depend on the degree of which the sensation of presence inside the RVE (another place than the nursing home) shows to increases exercise motivation for residents. It might also rely on additional perspectives suggested by motivation literature, concerning the particular orientation of the motivation, how to achieve it, and what to avoid.

2.4. INTRINSIC MOTIVATION

"Perhaps no single phenomenon reflects the positive potential of human nature as much as intrinsic motivation, the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore and to learn" [**101**]

According to psychologists Ryan and Deci, motivation should be understood as the phenomenon of being 'moved' to perform an action [**102**]. Individuals, who feel no desire to act on an impulse or engage in specific activities, can, therefore, be characterized as unmotivated towards these instances [**102**]. Besides being able to produce action, the value of motivation can be connected to increases in creativity and learning, enhancement of performance and persistence, and increases of self-esteem and wellbeing [**102**].

The lack of incentive to 'move' or produce action, reflects very well how residents at Akaciegården explain not to have the drive to exercise. As such, motivation levels towards the manuped exercise seem a valid measurement tool to indicate the presumed activity desire of a resident.

Self-Determination Theory (SDT) is a widely accepted theoretical framework based on the assumption that humans are inherently self-motivated, without the need for additional external reward [**101**] [**102**] [**103**]. SDT also proposes that motivation is multidimensional, and evaluated according to both its level (intensity) and its orientation (type). One of SDTs most fundamental ontologies lies in the distinction between intrinsic and extrinsic motivation. Intrinsic motivation occurs when individual performs an action exclusively because it is inherently interesting or enjoyable. Extrinsic motivation represents the opposite and is prominent when a person carries out a task because it leads to value found outside of the activity itself [**102**] [**104**]. SDT believes that self-determined motivation depends on three psychological needs [**102**] [**105**]: *Autonomy* (or self-determination); when the individual becomes the causal agent of his/her life. *Competence*; (or self-efficacy); when the individual has a perceived belief in his/her ability. *Relatedness*; when the person is enabled to share experiences and meaningful relationships. The sensation of competence is not able to increase intrinsic motivation without the existence of perceived autonomy.

At Akaciegården, the decision with residents not to exercise comes from their determination (as described in Chapter 3), not from external pressure from their surroundings (e.g. therapists, other residents or nursing home staff).

Autonomy does not trigger from external control, and increases in intrinsic motivation are dependent on how the individual independently perceives the value of an experience [**102**]. The incentive of the augmentation is therefore, ideally, to make a difference to the exercise experience, so positive that it will trigger their autonomy to exercise.

Competence is a relevant motivation aspect, from the perspective of the physical and cognitive challenges that most residents face every day, and which are also challenged during exercise. Competence (self-efficacy) can enhance intrinsic motivation through e.g. promoting/positive feedback and freedom from demanding evaluations, such as lack of strength [**59**] [**102**]. For body pain, the sense of competence might increase due to the distracting layer of the augmentation, by shifting attention away from the exercise-related pain [**14**] [**62**] [**63**]. Influences that undermine competence are tangible rewards, controlled directives, competition pressure, negative feedback, or focus on task performance.

Relatedness ironically represents the experience that residents are not able to get from the busy physical therapists. Relatedness would be a fantastic contribution to the exercise augmentation, but the interaction limitations of the residents, combined with the solitude of the manuped, means that this is not a motivational aspect that this project will attend. SDT also encompasses several additional subtheories to complete its framework [**101**] [**103**] [**106**] [**107**] [**108**], but these will not be further addressed.

To utilize autonomy and competence as measuring instruments with residents, the *Intrinsic Motivation Inventory*[4] (IMI) offers a variety of options. Its primary purpose is for laboratory experiments but can be used outside the controlled environment. IMI seeks the individuals' subjective experience of an activity, after said activity has taken place. It measures the level of intrinsic motivation from a set of seven factors/subscales: The *Interest/Enjoyment* (considered *the* self-report measure of intrinsic motivation), *Perceived Choice* and *Perceived Competence* (considered positive predictors of intrinsic motivation), *Pressure/Tension* (negative predictor of intrinsic motivation), *Value/Usefulness* (positive predictor of internalization), *Effort/Importance* (measures the activity's relevance to the subject) and *Relatedness* (measures the social connection to other entities or individuals). A 7-point Likert scale is used to evaluate all factors, where 1 is "not true at all" and 7 is "very true".

[4] www. http://www.selfdeterminationtheory.org/intrinsic-motivation-inventory/

Each factor has a variety of items, which can be combined to purpose. Results come from the averaging of item scores within each factor. Individual factors scores can then be used for analysis purposes. The IMI scales will be used in studies relating to residents' motivation to exercise, with factor choices relating to the purpose of the study.

As a multidimensional phenomenon (according to SDT), studies addressing motivation will hopefully provide insights to the level of several motivation factors. Brunet and Sabiston conclude how "*Identifying factors that influence intrinsic motivation and identified regulation for physical activity within each age segment is necessary to develop interventions to increase physical activity behavior across the lifespan*" [**43**]. Dacey, Baltzell and Zaichkowsky suggest that increases in intrinsic motivation have resulted in increases in physical activity with elderly users, and describe SDT as "*appropriate framework for studying physical activity motivation in this age-group*" [**109**].

CHAPTER 3. RESEARCH QUESTIONS

At the end of the introduction, I described the incentive of the project to be the exploration of combining older adults, immersive virtual reality and exercise motivation. It has since become apparent how the importance of exercise for older adults is strongly linked to their individual independence and quality of life. Moreover, the size of the elderly demographic is increasing, and how this will continue to require increasing societal resources. The issue is apparent in nursing homes, where limited staff resources for physical therapy require therapists to find ways to occupy many of the resident visitors in exercise activities that require no personal assistance. The result is that manuped, an exercise found trivial and uninteresting by residents, is unquestionably the most frequently used exercise platform at Akaciegården. However, the manuped itself does little to motivate exercise, which is already an activity related to personal obstacles such as accessibility, body pain, and arthritis.

Literature referenced in Chapter 3 suggests that the advantages found in VR-based rehabilitation can improve exercise experiences, with custom designed feedback loops in which real world actions are augmented and contextualized in virtual reality and placed inside virtual environments. This can provide constructive interference for the specific rehabilitation purposes, if correctly based on the objective of the activity and performance level of its users. The physical actions required from the manuped are already challenging for most residents. Low body strength, motor skills and cognitive abilities of residents mean that introducing additional physical interactions to the manuped augmentation would likely disturb the exercise routine more than the opposite. The mediated feedback from the augmentation should, therefore, be the only addition to augmentation, and needs to have a logical purpose, which exclusively connects it to the manuped pedal activity. VEs can simulate realistic and ecological locations. Due to the homebound lives of nursing home residents, having the opportunity to experience locations different from the nursing home might be an interesting asset. Literature suggests that nature exposure produces cognitive and physical benefits, as well as promote exercise activity. Given the urban surroundings of the nursing home, I assume that nature-based VE experiences can become an enjoyable and motivating addition to the manuped user experience. The literature on design guidelines for custom made recreational VEs is sparse, but does suggest the priority of specific content types. It also suggests that navigation guidelines could aid the recognition of VE locations, which might assist residents to remember the VEs, and thereby support the desire to return to the exercise platform. However, more information concerning recreational design in VR is needed. If exercise motivation does, in fact, increase for residents following the RVE augmentation, these aspects of the user experience need to be documented.

These points pose the following research questions:

RQ1. *How is motivation to exercise influenced for nursing home residents, when augmenting a manuped exercise with recreational virtual environments?*

RQ2. *What design aspects should a developer prioritize, when creating recreational, biking-oriented experiences in VR for nursing home residents?*

Working with virtual reality has to include considerations of its presentation methods. The impact of differences in immersive properties of a VR system is not trivial, and the difference between low and high levels of immersive displays can affect the user experience noticeably. Increasing immersive system properties often lead to an increased potential for a sense of presence. If residents are motivated to exercise by the experience of RVEs, a higher sense of presence inside the RVEs might influence exercise motivation. However, increasing immersive properties with particular technology, such as an HMD, will introduce a wearable, might impact the exercise experience negatively by the increase in interaction complexity within the augmentation. The literature on varying immersive system properties with nursing home residents is very limited.

RQ3. *What is the relationship between the sense of presence inside a VE augmentation, and the level of motivation to exercise, for nursing home residents?*

RQ4. *What are the advantages and disadvantages of introducing highly immersive technologies into VE augmented manuped exercise for nursing home physical therapy?*

The literature implications found until now, are encouraging for the direction of the project. However, despite how the majority of research on the Nintendo Wii and older adults suggests that the Wii is very useful as a physical therapy platform, this was opposed by the focus group trial at Akaciegården (as described in Chapter 2). This indicates that the context of this particular user group is unique and very diverse. It also hints that performing studies at Akaciegården often felt like uncharted territory, and that seeing the relationship between residents and the VE augmentation development was fascinating.

CHAPTER 4. REFLECTIONS ON METHODS

To address the aforementioned research questions, various methodological procedures were adopted and interchangeably used over the course of the project. The project underwent several phases, each representing the papers included in this dissertation, as can be seen as a schematic overview below in Figure 6.

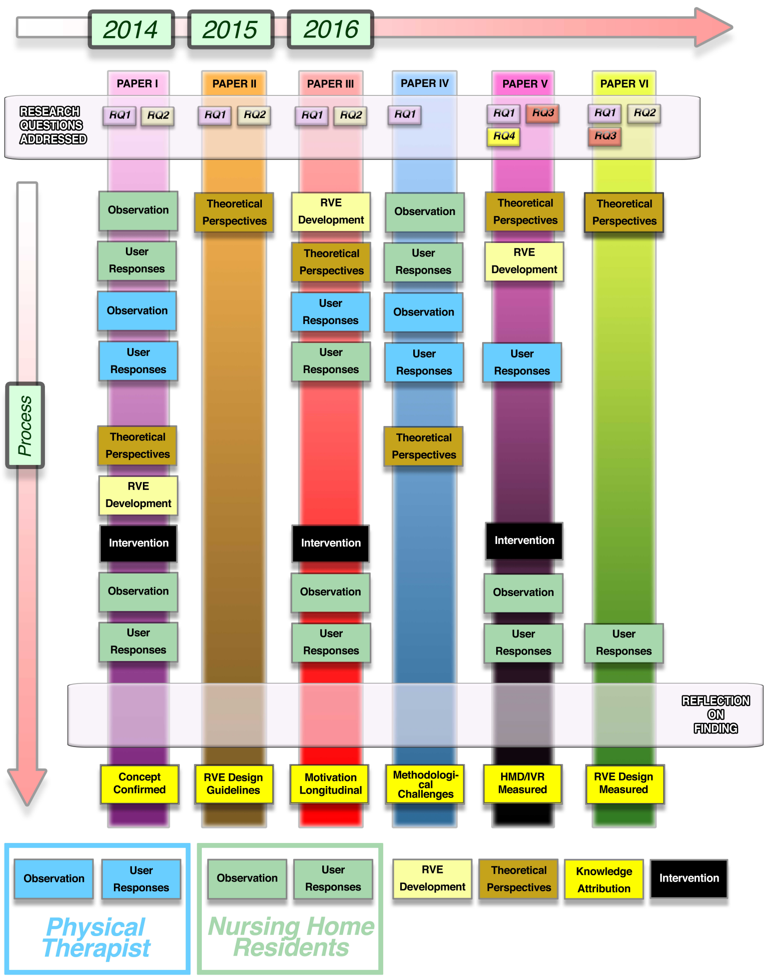

Figure 6 - Overview of the main methods adopted for the included papers

Figure 6 is a simplistic overview of the processes for each phase of the project, which led to each of the included papers. Each column represents each phase, and shows the individual steps performed within the phase as boxes in a descending sequential order. The steps that represent resources for knowledge are theoretical perspectives from literature, user responses or observations from either therapists or residents. Other steps describe activities such as RVE development or interventions at the nursing home (augmentation iterations or larger interview procedures). At the bottom of each column are two steps, which are repeated in each column; a reflection step and a knowledge attribution, respectively being the analysis of study data, and the area within the project attributed by the study. Atop each column are representations of which research question (RQs) to which the individual study has been attributing. This relation will be further elaborated in Chapter 7.

As seen from Figure 6, several studies have been utilizing similar methods, but with different sequencing. In Paper I, resident oriented observations and initial user responses led to the appropriate focus for theoretical directions in literature, which resulted in intervention and further gathering of user responses. In Paper III, theoretical considerations from both Paper I and Paper II allowed the technological implementation of the four RVEs, followed by literature studies on intrinsic motivation theory. This led to pre-study user responses from physical therapists concerning possible improvements to the augmentation and study methods/procedures. Only then the initial user responses for data gathering and observation of user interaction could begin, etc. In Paper IV, a rationalization of experiences, gained through user responses and personal observations from papers I-III, were used to elaborate on the project and its academic challenges regarding its users and context. In Paper V, the theoretical implications of immersive system properties and presence led to an intervention introducing a Head Mounted Display to the augmentation. Observations and insights through user responses were collected during the intervention. In Paper VI, theoretical foundations found in literature, led to a series of interview rounds with residents, concerning a spectrum of aspects of their RVE experience. The responses provided suggestive insights to the relevance of several types of restorative content, and some useful design indications in relation to future RVE designs.

Physical therapists as resources

Due to the limited literature on VR rehabilitation for the particular user group, residents and especially the physical therapists became an important addition to literature, as resources to guide project progression. In all phases of the project, the physical therapists were included in processes relating to forming participant lists, guide resident-oriented courses of action, or updating me on specific details concerning individual resident diagnoses or personal contextual situations (as this might affect the research oriented interaction). Therapists were also included in pre-study participatory design evaluation of all iterations of the augmentation. This proved an important step and afforded several smaller changes to the augmentations, such as decreasing bike speed (even further) for the HMD implementation. Therapists also assisted in the data collecting procedures in relation to the longitudinal study in Paper III, when I was not able to be present at the clinic. They were an invaluable help for the project, reporting incidents (such as if the augmentation would stop working), and represented the on-site stability necessary to keep the project moving when I was not able to be present. As an outsider, I would also acclimatize using them as examples, when e.g. returning to the nursing home after being absent for a period. At these times, I would have lost some of my intuition on how to approach and communicate with residents. Discussing approaches and observing therapists in their daily routines with residents, helped to rebuild my social skills toward residents. Re-obtaining fluid interactive skills would often require a week the nursing home.

Resident interaction

Observations of residents were necessary throughout the complete duration of the project, to understand residents' behavior with the augmentation and their social behavior. The latter had relevance, due to its importance to data collection procedures. Several studies used observation as part of the data collection method, concerning residents' behavior during exercise. Examples are Paper I and Paper V, where observations of behavior through video recording, played a significant part in the analysis of data. 'User responses' from residents in Figure 6, relate purely to study-oriented sessions. Conversations outside these sessions were very important, especially for maintaining a personal connection to residents, but these were kept to other topics than physical therapy. It might seem an obvious opportunity to use casual conversation to retrieve user feedback about the exercise experience. However, residents rather wanted to talk about their own topics and memories when given the opportunity, and I preferred to follow that lead and thus represent an individual who also cared about their individuality rather than only my research. My personal intuition was that investing interest time in casual conversations would give merit to situations when residents were asked to focus on the project. This, and several similar aspects of working with nursing home residents are described in Paper IV, which highlights that the personal connection and sense of trust is very important to residents.

Data acquisition methods

Over the course of the project, methods for data acquisition methods were changed several times, in search of the most fruitful approach, for both residents and data collection. As previously stated, detailed data retrieval from nursing home residents can be frustrating, due to their low energy, lack of ability to express themselves in detail due to language and reflection problems from cognitive deficiencies, etc. The pilot study (Paper I) applied an explorative, semi-structured in-situ interview approach, in a loose format with a wide selection of questions. It worked, but also suggested a cultural gap between researcher and subject, concerning the understanding questions and providing detailed answers. A different approach was taken in Paper III, both to attempt simpler responses using a 7-scale IMI Likert scale to measure motivation, and also a desire to use validated measure instruments. This approach illustrated different challenges. The IMI procedure is originally a questionnaire, but due to various limitations (eyesight, motor skills and cognitive disability), many residents were not able to read, write or understand the meaning of the 7-scale. In addition, the concept of the 7-scale rating was highly unintuitive to most residents, which meant that a) items had to be read aloud, and b) the process of answering items became a quest for the interpretation of what a number on the 7-scale meant to the resident. The result was an uncomfortable and long procedure for both parties during sessions.

4.1. UNITY3D DEVELOPMENT

The RVEs used in the project were constructed using the Unity3D 4 Pro (Unity3D) software, which is one of the premier toolkits for VE implementation. The RVEs in this project can both be seen as part of the research focus, and as a tool that allows the project to answer some of its other research questions. As such, developing the RVEs can also be included as part of the methodology of the project. This section will address some of the considerations related to the development process, primarily to highlight a few of the challenges of including the restorative aspects described in Chapter 3, while maintaining a build that is possible to run with an acceptable performance. Unity3D is an accessible tool for beginners. Simple implementations of 2D or 3D VEs are quick to make, and often require little computational performance. Unity3d is also complex to master [**110**], and comprehensive implementations become challenging from at least two perspectives; development time and performance optimization.

Figure 7 - A resident exercising on the manuped augmentation, in this case using the 46' LCD TV for visuals, and 2.1 stereo speakers for RVE soundscapes.

All four RVEs were built from the ground. For content, the RVEs made use of purchased content from Unity3D's Asset Store. The Asset Store is a market place for the community to purchase (or sell) community-developed products, either in the forms of functionality (scripts) or content packages. The majority of content for the RVEs were obtained from community developer K4 Manufactura , chosen for offering the highest quality, ecologically oriented nature content on the Asset Store.

When reviewing reference material from the real world to inspire RVE designs, it becomes apparent that nature environments have astounding complexity, individual ecological identity and complexity. Recreational spaces often represent a composite of rich details and variance. Environment 'lines' are organic and filled with 'anomalies' to break any form of synchrony or repeatability, despite e.g. revolving around the hypothetically smooth line of a trail, (extreme example in Figure 8).

Figure 8 - Mountain road used for inspiration[5]. Details when looking close, is extreme.

In Figure 8, the only near-path elements are a few bushes, some trees, the trail and rocks. However, if attempting a similar implementation in Unity3D, the randomness, and collectiveness of objects (for example, the rocks) is not trivial to reproduce. It quickly becomes 'composed' and thus appears artificial. For development, it raises the issue of time constraints (due to the 'design' of

[5] https://upload.wikimedia.org/wikipedia/commons/4/46/Mountain_window_path_DuckPass.jpg

randomness) and performance issues (due to the immense computational requirements of rendering all the individual objects). As a necessary solution, the RVE designs (such as Mountain Top, shown in Figure 9) rely on sculpturing the generic 'ground' plane (called terrain) to simulate e.g. rock formations in a crude fashion. Combined with high-resolution textures to simulate e.g. granularity and detail with larger geometric objects, the transition between terrain and 3D objects becomes unclear, which makes the illusion of rocky surfaces convincing.

Figure 9 - Mountain Top location, with much less granular geometric details, compensating with large geometry and high-resolution textures

Between RVEs, the complexity of designing these illusions lies in their individually defining features/content types. In Figure 10, another reference image shows the Keukenhof Park in the Nederland. The park path is clearly man-made, controlled and smooth, not irregular, like the mountain example. The granularity of the rock-dominated mountain terrain is non-present. One of the complexities of the park environment lies in its sculptured, small-scale vegetation areas, and the meticulously cultivated landscape architecture. From reference material such as Figure 10, parks also prioritize open areas. For implementation in Unity3D, the park environment represents different challenges than the mountain. Similar to the mountain, there are large amounts of detail to be mapped and placed, and while the park accounts for a more structured layout, nature is not structured. Putting flowers next to each other will quickly seem artificial if not placed 'purposefully random'. The result of the RVE adaptation of the park features can be seen in Figure 11.

The large variety of content needed to replicate nature, in particular between the different RVEs locations requires a diverse content library. Eight content packages from K4 Manufactura (nature, winter, park, medieval, autumnal, tropical nature and two rocks packages) and a few additional packages (dynamic birds, buildings, textures) were purchased for the purposes.

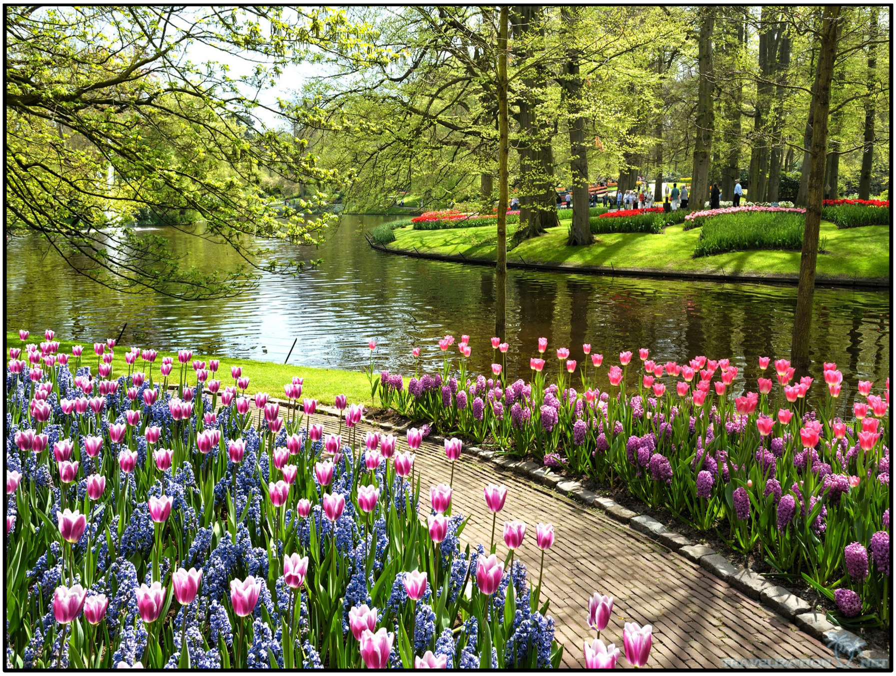

Figure 10 - The Keukenhof Park in the Nederlands. Inspiration for the Lake Park[6].

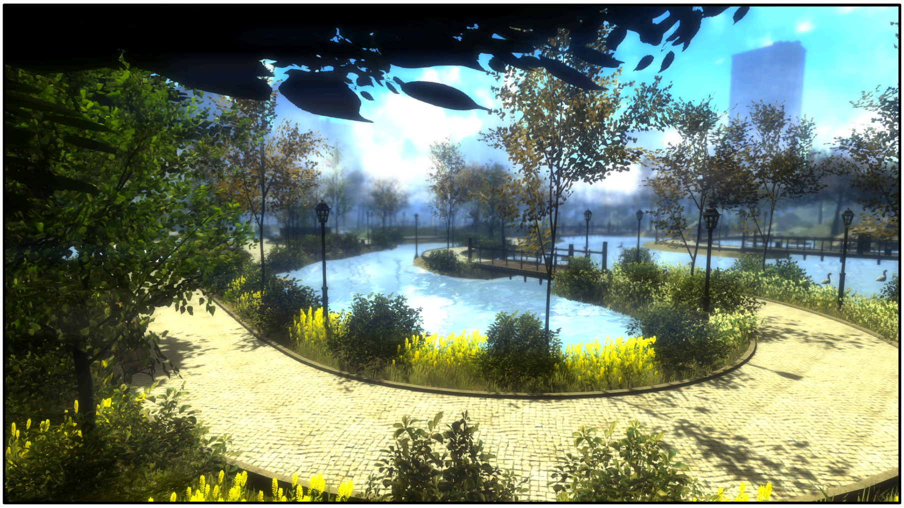

Figure 11 - Lake Park RVE. High quantity vegetation, lighting and water make this RVE very hard to performance optimize, without noticeable negative effects.

[6] http://www.travelization.net/2012/06/the-most-beautiful-gardens-all-over-the-world-wallpapers.html

Performance optimization

From a performance optimization perspective, the large quantities of details such as plants and trees combine poorly with far viewing distances. Objects within viewing distance need to be rendered, which requires computational power. Besides, RVEs needs to be lit (and shaded) by the Unity3D lighting engine. Real-time shadows, cast on and from RVE geometry, and transparent objects such as water, clouds, etc., are some of the most demanding computational tasks for runtime rendering. This made the task of constructing the RVEs challenging and with a continuous learning curve throughout the development process. Fortunately, computational performance can be monitored. Many prominent optimization aspects were found through the Profiler tool (Figure 12) within the Unity3D software. It allows monitoring of runtime performance and was invaluable for development.

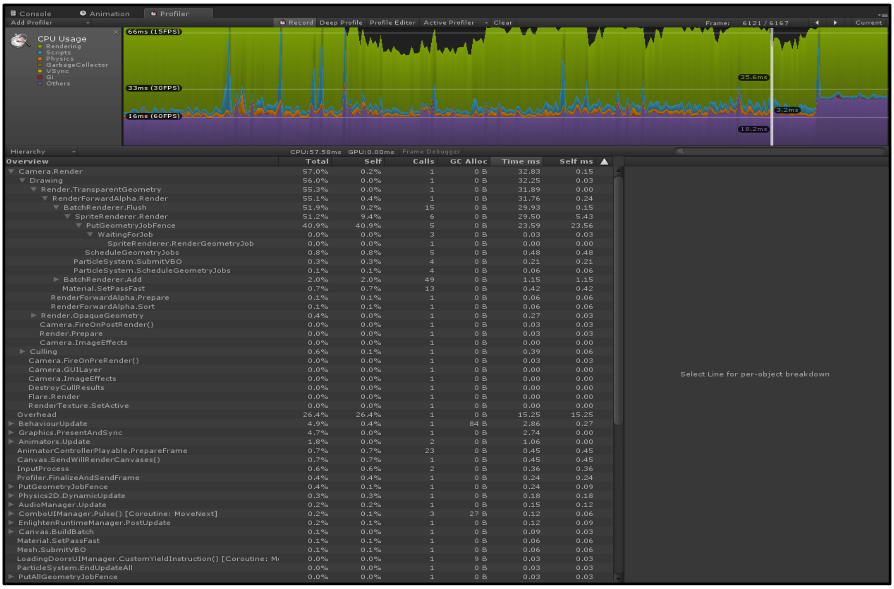

Figure 12 – The profiler function in Unity3D. It is a very useful tool for monitoring runtime process performance, and its effect on the frame rate update.

Prominent optimization effects came from the following aspects. Detail level according to viewing distance: for example shadow draw distance, gradual geometry detail improvement, draw distance for small-scale vegetation, tree geometry quality based on distance. Complexity control: for instance water complexity, shadow complexity, overall geometry complexity, and texture resolution. Pre-rendering: for example baking directional light onto geometry textures. Limiting quantity of objects requiring high computational power: for example dynamic objects such as birds, light sources, and transparent objects such as water, fog and clouds. Occlusion culling: for instance limiting the drawing of objects to exclusively the field of view of the VR camera.

However, this is not always efficient in open area VEs. The considerations above were vital to delivering VEs with the richness required for a restorative approach to the augmentation.

4.1.1. SETUP

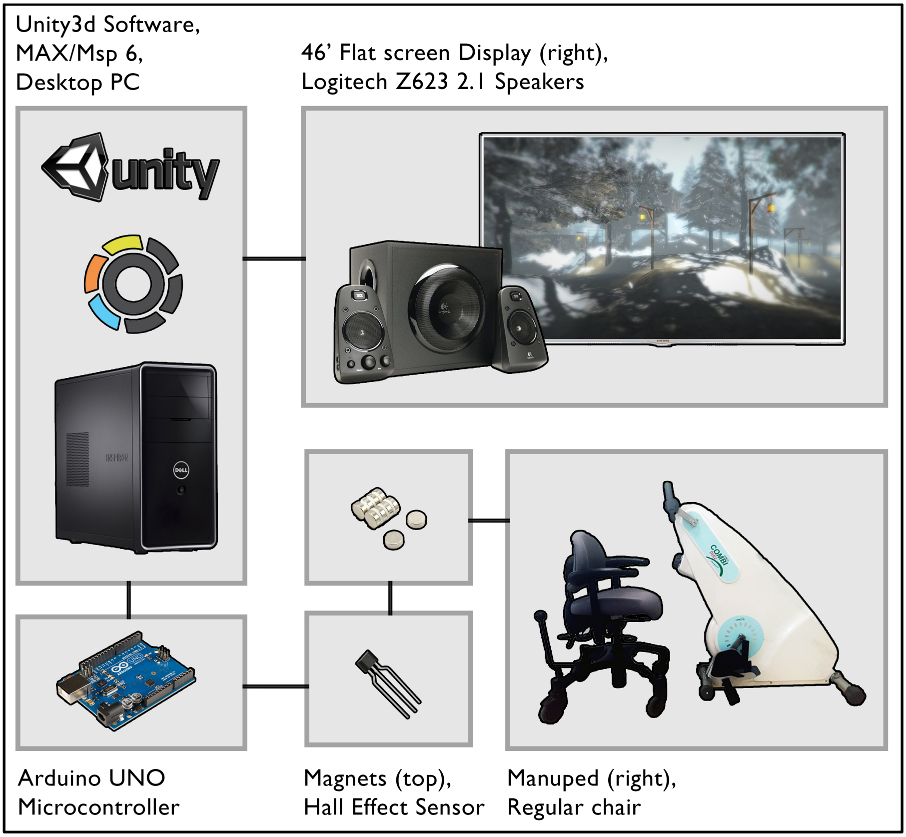

Figure 13 - The technical setup for the RVE exercise augmentation

The technical setup for the augmentation is shown Figure 13. The manuped had a magnet placed on its pedal arm according to a magnet sensor on the cabinet for pedal tracking. The sensor was connected to an Arduino UNO microcontroller, which sends the signal from the sensor to the desktop PC. Here it is processed in software by a MaxMSP patch, and passed to Unity3D. In Unity3D, the input signal is interpreted by a selection of custom made scripts, which indicates that the VE camera should move forward. The result from pedaling thus becomes visually displayed forward motion along a fixed path inside the RVE.

4.1.2. USER PROCEDURE

During daily operations, physical therapists help residents start their exercise routine with the augmentation. The Unity3D build is started from a desktop icon in Windows, after which a menu screen appears with image representations of each RVE (as seen in Figure 14). The images serve to help residents remember which RVEs are available and to make the choice easy. When an RVE has been chosen, the physical therapist just presses the image with the mouse cursor, and the RVE appears on screen, ready to move according to the pedaling. Driving speeds inside the RVE varies with pedaling speeds. Meanwhile, both lower and higher thresholds to the speed inside the RVE were set, in relation to pedal frequency. This was important, as the difference in exercise ability between residents was noticeable. If the speed/pedal round would be based linearly on the 'healthy' residents, the weak residents would never reach forward momentum due to their too low pedal frequency. Conversely, healthy residents would reach racecar speeds if the augmentation speed would be set linearly for the weakest residents. As a consequence, the weak residents would be able to obtain forward momentum, but 'healthy' residents would have an upper threshold to their speed. In practice, this was achieved by setting a particular gain for forward momentum in Unity3D, and set a limit to how often MaxMSP would be able to trigger a response to the signal from the magnet sensor on the manuped.

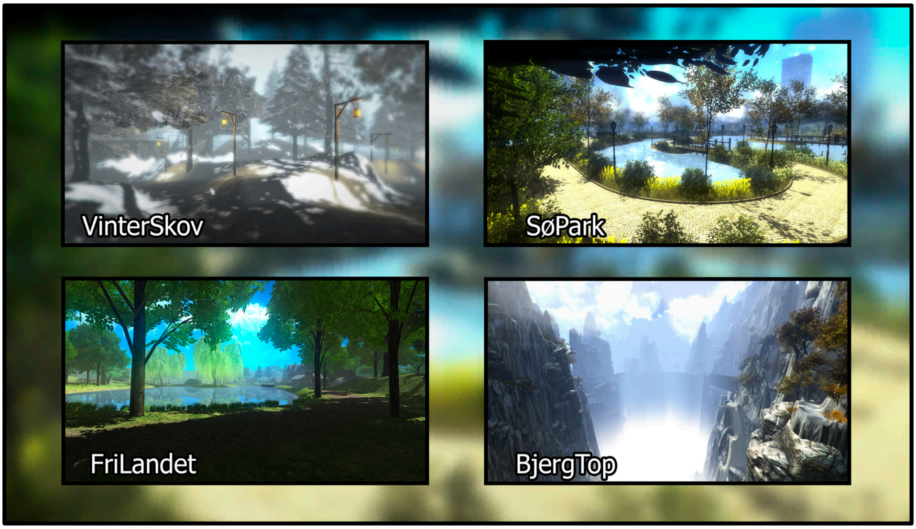

Figure 14 - The menu screen for the manuped augmentation. RVEs from top left: VinterSkov (Winter Forest), SøPark (Lake Park), Frilandet (Country Side) and BjergTop (Mountain Top)

4.1.3. CONCLUDING REMARKS ON METHODS

The schematic overview in Figure 6 illustrates the main steps of each paper included in this dissertation, as a beeline running through the project. It makes the project appear straightforward, with little to no obstacles along the way. And while there have been many truly enjoyable aspects of the project, my personal memory is not without the recollection of select challenges and disappointments.

Of the quantity of residents frequenting the physical therapy clinic, only some were eligible for study participation. Elimination of possible participants typically stemmed from severe cognitive or physical disabilities, preventing their ability to understand fully or communicate, or operate the manuped due to low muscle strength or amputated limbs. The number of eligible participants varied over the course of the project, depending on the current state of health with the inhabiting residents at the time.

Having a nursing home as the situated context of the project is a challenge. Working with nursing home residents means never being fully able to expect anything. This relates to a few different aspects. First and foremost, patience is a necessity when working with residents. I believe that spending casual time with residents to connect socially was beneficial for the project. A personal connection to residents often felt like a contributing factor to trust in the safety of participating in studies. This perspective is explained in more detail in Paper IV. Establishing this connection takes time. And when established, maintaining it takes time. Progressing through study participation takes time. Most conversations are mono-directional, about residents past lives and memories. And the majority of conversations are repetitions of the previous conversation, due to dementia. Some even include several repetitions per conversation, due to intense dementia. And this is fine, but it takes patience.

Patience and a flexible relationship with expectations concerning study sessions are essential from a procedure and planning perspective. Planning of studies was difficult, as some residents would initially agree to participate, but abandon the agreement on the day of the session, or during ongoing procedures spanning more than one session (paper III and paper VI). Of course, residents did not abandon studies from bad intentions, but due to physical or mental illness, or the occasional occurrence of death. But it did mean that my personal expectations to the study outcome needed negative adjustment concerning n participants unless a solution could be found. However, mostly this did not happen, and that the study would simply have to continue under the circumstances.

It is from these reasons that some studies in this dissertation suffer from relatively low n participants. Particularly in the later studies, it was tough to find healthy residents, who qualified to both operate the manuped and be able to produce meaningful sentences. From a procedure perspective, having residents express their opinions concerning a session item, could entail one of several situations. Either very long ‘thinking breaks’, which more seemed like the resident sleeping with open eyes. Or it was required to perform countless reformulations of study items, for residents to either understand the question or understand the concept of their response options (such as a 7-point scale). With participant responses or interviews, there was also a fine line between strictly keeping to the study procedure and ‘allowing’ residents to interrupt the procedure with an unrelated topic of conversation. On some occasions, sessions had to be stopped and resumed another time, due to a resident spending all available energy telling several stories. In other cases, residents ran out of energy before the conclusion of the session, without talking much at all.

The low number of participants in the studies has distinct effects on the substantiality of the following results. Increasing the number of participants would increase the validity and allow statistical analysis of quantitative aspects of studies. Under the current frame, results remain suggestive, which is regrettable. But it has been the circumstances of the project. With a larger pool of resources been available, more nursing homes could be included in the project to broaden the perspective and increase participant count.

These are but a few of the challenges related to having residents as the target audience, However, working with the nursing home residents was fundamentally rewarding. They are a very thankful user group to work with, once they realize that they can trust the intentions, e.g. of an external researcher.The use of Unity3D was a useful tool to create the VR experiences, but at the cost of expensive lessons from a steep the learning curve. The significant technological development of the four RVEs came before Paper III and is represented in Figure 6 as a box (step). However, the most accurate illustration of the RVE development would be as a separate phase (column). In many ways, the RVE represents the largest single challenge of the entire project.

I had no experience with Unity3D or similar software, prior to the project. One might compare this inexperience with a musical instrument. You might be familiar with the sounds and music it’s capable of producing, but you have no practical idea how to replicate it. As the practical experience slowly accumulates, a deeper understanding of the instrument emerges. The new techniques learned allow you to discover and appreciate subtleties, which you never before knew to be part of the music. Several initial RVEs were thus discarded or partially deleted, due to novice mistakes related to hopeless runtime performance, inefficient development methods and (personal opinion) clumsy, unaesthetic designs.

As the RVEs locations eventually settled and increased in complexity, the software became unstable and started to crash. Crashes often deleted hours of work. Precautions were taken by introducing an online backup server for frequent uploads. While still delaying the progression of the RVEs with every crash, it probably saved the project. At the end of development, Unity3D had become unstable to the degree, where some crashes would delete entire RVE scenes (file on hard drive, hundreds of work hours). If not for the external (to my hard disk) online server backup, there would have been no possibility of retrieving the lost RVEs. Downloading the latest backup repeatedly, and spending hours rebuilding lost content for every crash or RVE retrieval from the server delayed the project progression noticeably and stands as the most demotivating workflow experience in my current academic memoires. Ultimately, the efforts manifested in the final RVEs, and results of their implementation with residents became a rewarding experience onwards.

Another consideration, which has not been previously addressed in this dissertation, is the multimodal potential of the augmentation. From its inception, it was the ambition of the project to also investigate multisensory aspects of the residents' user experience with the RVEs. Plans included quantitative evaluations on different sound and haptic delivery methods. For sound, a combination of directional sound and open space sound delivery so that the exercising resident would receive sound effects local to user position in the RVE, and the physical therapy space could be filled with restorative soundscapes corresponding to the RVE location. Another idea was to use wavefield synthesis 3D audio as a method to increase the immersive system properties. There were also plans to incorporate haptic feedback to the chair of the user, simulating the haptic sensation of the surface texture of the path, with accompanying surface sound effects, as an increasing immersive system property, to measure the sensation riding through the RVE (corresponding to accompanied surface sound effects).

These plans were discarded early in the process; once I began to understand the context of the project. In relation to audio, all RVEs had custom made, individual soundscapes. In the study for Paper III, the setup included capable 2.1 speakers. Physical therapists were encouraged to use it, but also 'allowed' not to, if the therapy environment on certain days would become negatively affected by it (e.g. increasing the overall noise level in the clinic to an unproductive level). Over the course of the study, I saw how the soundscapes were gradually being turned off, to the point where it was never used. This was logical from the perspective that many residents have terrible hearing. Even without the soundscapes turned on, therapists most often have to raise their voices (though not in a negative fashion) to be able to communicate with residents. Since the concept of wearing headphones had been given negative reviews by residents in a pilot study (Paper I), further investigations into the auditory aspects of the augmentation were henceforth parked.

Moreover, I have also worked in parallel with other Ph.D. students, who have performed quantitative studies with ‘normal’ subjects, in a controlled laboratory environment. Following my colleagues’ work, I could see how even some ‘normal’ users would often struggle to perceive the difference of a 64-channel wavefield synthesis system compared to more conventional setups. And if they were able to, nursing home residents would definitely not either.

For haptics, the idea was to create a custom chair with haptic actuators for the residents to sit on when exercising. In the period of the project, where there would be time of the haptic interaction, the number of possible participants not operating the manuped from their wheelchair was too small. As the haptic devices would need to be attached to the chair of the user, the idea was dropped, for focusing more on the HMD.

CHAPTER 5. SUMMARY OF INCLUDED PAPERS

In this chapter, a summary of the included papers is presented. Paper I is the first explorative approach to introducing residents to the concept of augmenting the manuped exercise, in this case, with a very simple VE. Paper II is a literature review on the design approach to RVE development for non-architect or landscape design developers. Paper III is a longitudinal study on the effects on intrinsic motivation when embedding the manuped augmentation in the physical therapy routine over a 4-month period, using four restorative oriented RVEs. Paper IV is a reflection on the project and the method considerations inherent to working with nursing home residents. Paper V is a study on the effects on the exercise motivation as a function of the sense of presence, using an Oculus Rift DK2 HMD to increase the immersive system properties of the augmentation. Paper VI is an evaluation of the restorative approach to the VE augmentation, concerning its effect on the user experience and indications on restorative design recommendations for developers.

PAPER I: Augmented Exercise Biking with Virtual Environments for Elderly Users: A Preliminary Study for Retirement Home Physical Therapy [111]

Motivation: Exercise is essential for older adult nursing home residents to retain their physical independence. However, many nursing home residents at Akaciegården nursing home in Denmark do not exercise sufficiently. It has been shown that VR technology can contribute positively to the exercise experience of older adults. This pilot study explored whether residents can embrace the concept of an exercise augmentation, using a virtual environment to contextualize the bike-reminiscent exercise actions, and highlight which parts of the experience that should be taken onwards for further development.

Methods and Materials: Several iterations of measures went into this study. A preliminary qualitative study (*n=16*) showed that body pain, laziness and lack of interest were the dominant reasons for not attending physical therapy exercising, or wanting to use the manuped exercise device. Literature suggests that elderly are proponents of technology as long as they understand the purpose and see the need for its functionality [**13**]. It also suggests exercise-oriented media technology has been useful for rehabilitative purposes, useful to activate elderly users, and that virtual environments are able to create a connection between real world actions and virtual world feedback [**13**] [**14**] [**16**] [**17**]. This allows independent explorations of environments comparable to the real world, under circumstances that are safe and possible to alter to fit user needs or limitations [**59**]. A manuped was augmented with a simple VE created in Unity3D, displayed on a 46’ LCD TV, with a soundscape audio through headphones. The VE had a circular trail that took approximately 4 minutes to ride, and could be driven endlessly if needed. The interaction design was kept identical to the conventional exercise. The only interactive element to the augmentation was forward-motion inside the VE, simulating the activity of driving forward along a trail. Navigation was automatic and followed the trail. Participants tried the augmentation once until they wanted to stop. The study used an 11 item in-situ semi-structured qualitative interview to conduct with participants while active with the system. The interview investigated four themes; 1) opinions of being exposed to the VE (3 items), 2) details about the exercise experience (3 items), 3) if they felt a connection between exercise actions and VE behavior (2 items), 4) if they believed such type of experience would increase their desire to exercise (3 items). Of 15 proposed participants, 10 attended the trial.

Findings: Participants reported that the exercise augmentation was able to contribute positive elements to the exercise experience. The unchanged (simple) physical interaction suggested no issue, as the majority of residents reported to enjoy their exercise, despite the simplicity of the augmentation. The majority enjoyed the exposure to the VE by the augmentation (theme 1). Residents felt a connection between their actions and the VE behavior (theme 3). Responses relation to theme 2 included how the augmentation introduced a sense of purpose to the exercise actions, an overall sense of accomplishment and a welcome opportunity to travel to an otherwise unknown location (which was positive). Participants were observed to stop and enjoy the view of the VE, and enjoying it, with comments regarding a perceived beauty of the VE. Some participants expressed an overall impression of 'being' in the VE, and commented on specific objects they either enjoyed or in some cases found unfitting. Improvements to future designs were needed, relating to additional and larger VEs with more diverse content, the ability to select between different locations, more 'life', and more 'realism' within the VE design from more coherent content to make the impression of the location seem more believable. For theme 4, the majority of participants expressed that they would prefer the augmentation to the conventional exercise, if possible, and believed it would increase their exercise frequency.

PAPER II. Simulating Nature for Elderly Users – A design Approach for Recreational Virtual Environments [112]

Motivation: The encouraging results of the pilot study suggested that an exercise augmentation could potentially be able to increase the motivation to exercise. Previous participant responses gave useful insights to possible improvements to the pilot study VE, but only general comments. This review paper explored literature, to establish a guideline to the VE design process for future exercise augmentations.

Methods and Materials: The study looked into restorative effects of nature, advantages or disadvantages of using VE augmentations, previous studies incorporating VE augmentations – either as real world simulations or as contextualization for rehabilitation. The paper also searched for examples of content considered recreational, crucial aspects of creating a perception of realism in VR, and an approach to design from and overall level, as well as a detail level. Findings came from studies or reviews, scattered across fields such as tourism, landscape design, and architecture, VR simulation of urban spaces and urban design, psychology, VR rehabilitation, and VE navigation. The review also included the suggested improvements from participants in Paper I.

Findings: The review split the findings into two main categories for recreational VE; content, and features. Content related to concrete examples of recreational content found mentioned in other studies. Water, plants, and wildlife were among the most dominant entries, but a combination of many content types was recommended. Features related to either technical or artistic aspects of the VE presentation. Technical feature examples are texture quality, realistic lighting, scaling of objects, or reasonable VE behavior. Artistic features could be visual consistency between elements, subtle shading, light/shade combinations, or high image complexity. For the mapping and spatial overview of the content and the evaluation of some features, inspiration was taken from VE navigation oriented landmark typeset, which served to categorize VE objects. The paper placed content and features into landmark typeset categories to the degree possible, and added a few additional subcategories under respectively content and features, for considerations found in the literature that was outside the scope of the landmark typeset.

PAPER III. Motivating Elderly to Exercise – Recreational Virtual Environment for Indoor Biking [113]

Motivation: The pilot study had suggested that an exercise augmentation using recreational VEs could possibly increase motivation to exercise. The fundamental incentive for this paper resembled Paper I, but executed with a more thorough approach. The paper tested the concept of VE-based exercise augmentation in a longitudinal fashion over a 4-month period, to evaluate changes in level and orientation of motivation to exercise.

Methods and Materials: The study introduced four new recreational VEs. Their designs were made, using the VE designs guidelines from Paper II. The four new VEs will be further described and evaluated in Paper VI. The VEs were displayed on a 46' LCD TV, with corresponding soundscapes played through e 2.1 stereo speaker set. The interaction design was similar to that of Paper I. To measure the level and orientation of motivation to exercise, the study took reference to the theoretical framework of Self-Determination Theory (SDT), more specifically intrinsic motivation derived from the sub-theory Cognitive Evaluation Theory (COT). To measure the intrinsic motivation, the Intrinsic Motivation Inventory (IMI) was used as the measurement instrument. Of the inventory includes seven subscales (factors) for motivation orientation, from which five was used. Each factor has a variety of items to be used in studies interested in that specific motivation orientation. 17 items from 5 factors were used for a questionnaire. Factors were *Interest/Enjoyment, Pressure/Tension, Perceived Choice, Value/Usefulness* and *Perceived Competence.* The questionnaire also contained 3 additional items, concerning the a) *positive* and b) *negative* or c) *possible improvements* aspects to the exercise experience. The questionnaire was given to participants before the augmentation was implemented and twice after 4 months: one questionnaire about the VE augmentation experience, and one questionnaire about their perception of going back to the conventional manuped experience. The last questionnaire was to see the difference of opinion, now that residents had a foundation of reference between the augmentation and the conventional exercise. Of 24 prospect participants, 17 agreed to participate. Of the 17 participants, 8 were able to complete the 4-month trial. 4 participants joined the procedure during its run, but end results were represented by 3 groups of participant, representing (G1, $n=8$) a complete run, (G2, $n=4$) missing the beginning or (G3, $n=9$) missing the end of the trial. Reasons for missing the end of the trial were relocation to another nursing home (one participant), progressive illness, limb amputation, and death.

Findings: IMI showed that augmented exercise consistently received highest motivation ratings across the five factors. The post-VE evaluation of the conventional exercise was consistently rated least motivating. Due to the nature of the resident participation, conventional statistics were useless, but the *Interest/Enjoyment* factor showed to be the one prominent factor, noticeably different between VE vs. non-VE conditions, very positive towards the VE augmentation and quite negative towards the non-VE conditions. Combined with the 3 open-ended items, the pattern of the findings was that most processes related to the physical therapy work very well, which explains how 4 of the 5 motivation orientations had overall positive values and low dispersion, also between the VE and non-VE conditions. Qualitative responses also showed that residents' positive responses to the conventional manuped exercise related to long-term investments in health, whereas positive responses to the VE augmentation related to short-term experiences of the activity itself. Dominant positive responses related to the recreational direction VE augmentation, such as enjoyment and fascination with the experience of traveling the nature environment, details about the experiences and comments relating to the perceived (more resistance uphill) and behavioral effects (e.g. pedaling harder uphill and faster downhill) of the exercise contextualization. Negative responses to the conventional exercise related to the same areas as Paper I (boredom, physical demands, pain, laziness), whereas negative responses to the augmentation were fewer and less relevant for the study (less speed to have more time to look at the VE or general dislike for biking).

Despite how only the one motivation factor showed clear improvements, the change of the augmentation made a noticeable difference on the overall exercise experience.

PAPER IV. Nursing Home vs. Researcher: Establishing Their Needs while Finding Your Way [114]

Motivation: A book chapter in two parts. Part 1 reflected on the background and results from Paper I, and Paper III, in more detail than possible in those respective papers. Part 2 reflected on the inherent challenges of working as an (to the nursing home) external researcher in collaboration with nursing home staff, but especially its residents.

Methods and Materials: Part 1 elaborated on the background reasons for the problematic exercise situation, and the dynamics affecting the nursing home residents, and their relationship to exercise. The findings from Paper I and Paper III were repeated in this paper. Part 2 addressed research challenges such as planning of studies, the importance (and some methods) of keeping residents invested in the collaboration, the relevance of becoming a part of the everyday routine, and the crucial role of embracing personal relations with the residents. In addition, the paper reflects on some reoccurring issues concerning the introduction of exotic technology, and how to approach (and what to expect from) data collection.

Findings: Part 1 presented findings already suggested in the introduction of this dissertation, such as background on the older adult demographic, and the dynamics and reasons for the lack of resident exercise motivation at Akaciegården. Such as for instance the constant struggle to keep physical decay at bay with exercise, but regularly being subject to instances of illness, and having to start the whole, painful and difficult rebuilding process over again. Part 1 used these perspectives to further establish the role, rationale, and importance of the results from Paper I and III.

Part 2 reflected on the uniqueness of the nursing home user group, sharing experiences of the need for patience, planning, and complete flexibility when plans get altered due to participants' high age and related complications. Establishing and maintaining routines are crucial to making sure that residents are focused on their commitment to the research, and the researcher needs to use all possible angles (newspaper, posters, staff, own personal appearance, private visits, etc.). Part 2 also reflected on the need for sensitivity and empathy towards residents' boundaries and personal conflicts with many aspects of their lives, whether it be deaths or relatives, the obvious inevitability of their own death, memory loss, physical decline, etc. A series of reflections is also made on the need for patience to establish some significant milestones. For example the inter-personal trust between resident and researcher, and necessity for the researcher to find the courage, to encompass the many personal pains of the residents (physical or psychological) and meet them in dialogue about it, on their terms.

PAPER V. Going outside While Staying Inside – Exercise Motivation with Immersive vs. Non-immersive Recreational Virtual Environment Augmentation for Older Adult Nursing Home Residents [115]

Motivation: The immersive system properties of a VE representation can vastly alter the perception of the VE and its content. As it was suggested in Paper I and especially Paper III, the recreational experience derived from the designs inspired by Paper II, seemed to play an important role in the Interest/Enjoyment of the augmentation. This paper introduced an Oculus DK2 Head Mounted Display (HMD) for the visual display of the VEs, to explore if increasing the immersive properties of the exercise augmentation would have an effect on residents' sense of presence, and their exercise motivation.

Methods and Materials: As explained in Chapter 2, subpart 2.3.4, immersive system properties are able to affect a user's perception of a VE, to the degree that a user would potentially feel a sense of presence so convincing, that responses to the VE would be similar to responses in a real world environment. According to Slater [**3**], immersive system properties can be defined by their ability to display stimuli to all senses, and to convincingly track and display user behavior, transfer it to the VE and have the VE respond to this behavior [**3**]. If done convincingly, this should induce a high sense of presence, from the perceptual illusions of place (spatial transfer) and plausibility (that VE events seem 'real'). In this study, the Oculus DK2 provided increased immersive properties by stereoscopic imaging, as well as orientation and position tracking of head movement. The goal of the paper was to measure the effects on the sense of presence and exercise motivation, between two conditions, respectively displaying the VEs 1) on the 46' LCD TV used in Paper III and 2) with the Oculus DK2 HMD. The auditory display remained unchanged from Paper III under both conditions. The hypothesis was that an increase in the sense of presence would result in an increase in the Interest/Enjoyment intrinsic motivation factor (as found to the differentiating motivation factor in Paper III). 10 participants participated in the study.

All participants were required to have previous knowledge of the augmentation, as being able to recognize an already familiar augmentation and VE content, would limit the amount of novelty to the experience for participants. This would increase the possibility of participants evaluating the effect of the technology, not the novel experience of the VE augmentation itself and its content. An additional advantage of prior experience was being able to shorten the trial by omitting practical trials of the 46' LCT TV condition. Participants had already used it many times before, and would therefore already be qualified to answer items about this experience. The point of this was simply to shorten the session, as previous studies have shown that residents have a short window of energy when participating actively in trials. The study used the first 3 items of the SUS presence questionnaire and 5 items for Interest/Enjoyment. While exercising, residents were video recorded for qualitative analysis of verbal responses and behavior during trials. At the end of the session, residents gave their opinion on which condition they would prefer, if they had to choose only one as the choice of display for future exercising.

Findings: The sense of presence with the HMD condition (C2) was vastly superior to the LCD TV condition (C1). Motivation was higher with C2, but not convincingly (statistical significance tests are insignificant with 10 subjects). 5 of 9 participants preferred C2. Exercise durations were twice as short with the HMD than the average exercise session for the same participant, with the 46' LCD monitor. Observations were coded into four categories; Body Language, Facial Expressions, Exercise Behavior and IVR/SC Behavior (referring to Immersive VR/Sensorimotor Contingencies from Slater's terminology [**3**]). The qualitative data supported the high sense of presence felt by most residents, and even questioned a few of the preference choices of C1, suggesting that the percentage of C2 preferences perhaps should have been higher. However, observations also supported that an HMD might not be the optimal solution for the current physical therapy situation at Akaciegården, as it removed many aspects of the independence inherent to the manuped exercise. Without assistance, wearing an HMD while exercising on the manuped could be dangerous for residents, due to some participants complete lack of spatial and proprioceptive awareness while wearing the Oculus HMD. Findings also showed that no participant found the HMD uncomfortable to wear on their head, or uncomfortable to look through, but natural and intuitive, once it was on their heads.

Chapter 16. PAPER VI. Designing Recreational Virtual Environments for Older Adult Nursing Home Residents – How Nature and Content Matter for Improving Augmented Exercise experiences [116]

Motivation: With past papers suggesting positive measures for the concept of augmenting the manuped exercise with nature-based recreational environments. Paper II highlighting the need for more literature supporting the design principles and approach to recreational VE (RVE), the purpose of this paper was to collect insights into the effects of the particular role and user preferences of RVE content and overall design implications.

Methods and Materials: The approach of the paper followed in the footsteps of Paper II, concerning some of its reference to background literature and overall methodology. However, the subject matter was revised as a second iteration of Paper II, with an elaborated theoretical background, and improves the design approach 'package', most noticeable addition from Kaplan's four restorative components [**75**] provides a better understanding of the restorative user experience. However, the main contribution of Paper VI comes from a formal presentation of the four RVE designs used in Papers III and V, with an evaluation of the designs, based on the aforementioned design approach. The methodological approach to the evaluation was split into two parts.

Part 1: A review of recreational content/experience responses from participants in Papers III and V, coded from the perspectives of respectively Kaplan's four components, RVE content and RVE features.

Part 2: A three-part 'survey interview' (SI) (survey designs verbally presented to participants) investigating residents' experiences and preferences among the RVEs. SI 1 had 5 items, plus open-ended follow-ups, SI 2 had 20 items of simple preference choice, plus the possibility of elaborate comments) and SI 3 had 33 items, like images, to evaluate participants ability to recognize locations, content (or misc.) from all four VEs. Examples of the first two parts of the survey interviews, were preference among the four RVEs, believability of behavior, restorative effect (perceived importance of the nature orientation, any relaxation effects), the role, perceived importance and preferences of various types of landmark setups found in the RVEs, fascination aspects and path design. The last part of the survey interviews sought insights to significant traits of the four RVEs, in terms of content preferences and impact, proposed by the level of recognition by participants.

Findings: Findings suggested that the several aspects to residents' reported experience correspond with RVE design approach presented in the paper. The design approach can additionally function as a tool for structuring user responses to indicate whether a user existence contains restorative aspects. User responses from Paper III and Paper V suggested the restorative components be part of residents' exercise experience, and that the immersive system properties of the RVE display might increase the restorative effect of the user experience. The behavior of RVEs was unanimously confirmed as realistic and being situated in nature was unanimously confirmed as positive. Results suggested a preference trend toward the Lake Park and Mountain Top RVEs, but all four RVEs were chosen as the individual choice between participants. Results showed that residents were equally pleased with calm and 'dynamic' RVEs, but that large, and open/wide environments with long and straight paths (opposed to many turns and constantly shifting horizons). The number of route segments / intersections showed no clear indications.

The role of content and landmarks is especially interesting for this study, concerning the importance of recognizable content, and which specific content that would be most recognized/remembered by residents. Resident responses only partly supported Vinson's guidelines concerning recognizability, as residents reported the nature-based landmark example as equally recognizable to the man-made landmarks. However, a clear personal preference showed in favor of nature-based landmarks/content. But interesting, residents did not wish for recognizable areas or objects, but instead preferred the impression of experiencing new (unrecognized) locations. This means that the proposed benefits for location recognition by landmark placement might not influence the RVE experience noticeably. Whether it aids the memory of the RVEs is another perspective, but from the content/landmark recognition study, landmarks did not take a dominant role. Virtual objects, such as flowers, rocks, trees, and snow, were more frequently recognized individually, than the single most recognized landmark (lamp/lantern). Virtual objects were on average recognized twice as often as landmarks. In the RVEs, it must be mentioned that virtual objects also appeared more often than most individual landmarks, but this approach holds faithful to the formula from Vinson, where landmarks are singular, mutually isolated objects surrounded by 'supporting' virtual objects. The study merely suggests that while other user groups (different from nursing home residents) might focus on the individual objects, nursing home residents seem to concentrate more on the coherence of frequently appearing virtual objects. This suggestion is supported in the study results, by residents' experience of the Mountain Top RVE being largely based on scenic values as its 'district' (the landmark type for a whole neighborhood) identity. In other words, as the coherence of the RVE content, by recognition oriented responses as "the whole" (or 'the coherent entity'), more than its individual parts. And while the Lake Park RVE was not described explicitly with the same 'coherence' notion, it was largely recognized and appreciated by its most frequently appearing virtual objects, more than its 'remarkable' landmarks. Meanwhile, dynamic elements such as 'life' (wildlife, waterfalls, etc.) must not be neglected as a priority, as it was mentioned in other contexts as very important for the curiosity of traveling the RVE.

For future RVE designs for nursing home residents, the complexity of the current RVE designs might be unnecessarily high, for the augmentation to remain an efficient motivation factor for manuped exercise. The designs might need their overall focus on virtual object oriented 'themes', where the 'whole' that should be the priority, more than being centered around individual landmarks. It might even be more efficient to make several, simpler RVEs and one complex. As long as they follow the updates to the RVE results from this paper; close proximity restorative content such as rich and coherent virtual objects, straight paths that show wide open spaces with 'scenic value', wildlife, and differentiating route segments.

CHAPTER 6. CONTRIBUTIONS, CONCLUSIONS AND FUTURE WORK

For this dissertation, I set out to explore the factors influencing nursing home residents' lack of motivation to exercise and how using VR technology could positively influence this. Prior to this project, I had a personal ambition for years to work with VR rehabilitation, and the motivational aspects of exercise augmenting platforms has always made personal sense to me. Why not contextualize tedious activities, such as some forms of indoor exercise or rehabilitation activities, with fun or otherwise motivating interaction, if it enables us to promote our (physical and mental) health? Societal resource issues related to an increasingly elderly demographic can be seen in Danish national statistics [**2**]. It incentivizes how older adults (such as nursing home residents) need to maintain their health and independence for as long as possible. They should do this to retain their own quality of life. But sadly, individual independence might bow also become necessary, in relation to a forthcoming societal struggle for resources to care for elderly in need.

For nursing homes, this matter of resources will also become ever more apparent, and any measure to increase independence with residents should be welcome. Exercise should be one of the central measures. The use of VR technologies with older adults has proven relatively uncharted, especially rehabilitation applications with high immersive system properties, tailored for elderly users.

During the initial phase of the project, it became apparent that the manuped exercise device should be the activity to target, and that motor skill based interaction from an augmentation had to remain unchanged. This meant that a technological augmentation had to be placed as a 'layer' on top of the conventional exercise, in connection to its inherent actions. In consideration of the homebound living conditions of the nursing home residents and literature suggesting the positive influences of nature experiences, the technological intervention became a recreational leisure bike ride, through nature environments in the virtual domain. The question was whether residents would accept the augmentation concept of a virtual display connected to real world actions, and whether or how it would qualify as an experience that could raise their motivation to exercise.

This chapter will summarize and discuss the contributions relevant to each of the five research questions presented in Chapter 4, concerning how the project have been able to cover its goals, and where there might still be prospects for future work. For the sake of clarity, the research questions (RQs) will be repeated in the sections below, with a listed overview of the primary papers contributing to answering the RQ, and some additional reflections on the contributions of these.

Before approaching the RQs, it is important to mention, that one of the overall contributions of the research is the fact that the project has focused on fieldwork, including stakeholders (nursing home/therapists) and end users (residents). My fellow Ph.D. students, who performed quantitative studies in a controlled laboratory environment, did so primarily with other academic personnel as participants. At certain points during my project, I was envious by the idea of also having my testing ground be so close, controlled and available, with 'normal', capable users. But every time I had this conception, it became apparent to me every time that the context cannot and should not be taken out of this project. The user group and the situated circumstances of the nursing home are incomparable to that of a conventional laboratory environment. The nursing home thus became my personal 'remote laboratory'. And philosophically speaking, my controlled conditions became the fact that this was the most optimal setup I could ever get, to measure exactly whether and how my research would reach and affect its target in the real world, with all its twists and bends.

6.1. MOTIVATION TO EXERCISE WITH AUGMENTATION

RQ1. *How is motivation to exercise influenced for nursing home residents, when augmenting a manuped exercise with recreational virtual environments?*

All six papers included in this dissertation address this question address RQ1 to a certain extent. However, only some primarily addressed or contributed to the understanding of motivational aspects. Findings led to the following contributions:

- *PAPER I.* The perceived connection between residents' exercise actions and the behavior of the VE increased the perception of exercise accomplishment. Participants felt able to visit another place than the nursing home, and characterized VE content as beautiful.

- *PAPER III.* The augmentation increased intrinsic motivation to exercise noticeably compared to the conventional manuped exercise, by the specific factor of Interest/Enjoyment.

- *PAPER III.* The motivational increase with the augmentation was predominantly due to experiencing and exploring RVE content.

- *PAPER III.* Positive aspects to exercising changed from long-term physical benefits (conventional exercise), to short-term enjoyment of the activity (augmentation).

The contributions from Paper I were not part of a regular IMI item related measure, but from the perspective of Paper III, the results of Paper I already indicated the Interest/Enjoyment of the augmented experience. Paper I is given the credit as a contribution, from being the first study to suggest the experience of being allowed access to a different location than the nursing home, as well as the enjoyment and interest in the nature-oriented beauty of RVE content. Of course, these findings are supported more substantially in later studies, such as Paper III, Paper V and Paper VI. In Paper III, it was formally suggested that the intrinsic motivation to exercise was increased with the augmentation. Thanks to the multidimensionality of the SDT framework, intrinsic motivation increases were isolated to the factor of Interest/Enjoyment, which related to residents appreciation of the experience of enjoying and exploring the RVE content and overall design. The most interesting effect of this could be seen in how residents changed their approach to complimenting the positive aspects of the manuped exercise, by transitioning from a rational focus on the long-term physical benefits to the 'here and now' short term enjoyment of the activity. From early interview responses, described in Chapter 2, the manuped activity itself was isolated to be the probable cause of the lack of interest in maintaining a physical therapy routine. The user responses to the augmentation in Paper III suggest that this has been positively affected.

6.2. RVE DESIGN FOR NURSING HOME RESIDENTS

RQ2. *What design aspects should a developer prioritize, when creating recreational, biking-oriented experiences in VR for nursing home residents?*

- *PAPER VI.* An RVE design can be identified from the perspectives of its restorative components, content, features and spatial structure.
- *PAPER VI.* Virtual objects are the most important content type for residents' recreational experience, but the single most dominating factor for residents is 'the whole' impression.
- *PAPER VI.* The landmark typeset is a useful method of structuring content, but its theoretical navigation advantages for recognition purposes is not important with nursing home residents.

As a process begun with Paper II, the RVE design approach became an integral part of the project, by guiding the development of the four RVEs used in the majority of the papers included in this dissertation. The rationale behind not including Paper II in the list above is due to the later adaptation of its principles in Paper VI, where the design approach was refined and used to describe and evaluate the four RVE designs used throughout the project. Findings suggest the contribution that the design approach allowed the identification of restorative elements in user responses from previous studies, a theoretical presentation of the RVE designs, and a baseline to evaluate the residents' experience of the role and preferences of the RVE design aspects. From user responses, virtual objects stood out as the most dominantly noticed content type. From the RVEs constructed for this project, flowers, rocks, snow, trees, and water were the principal virtual objects. However, what was suggested by the results was a trend for residents to remember content based on the 'themes' of the RVEs, as an identifier of their recollected experience. This opposes Vinson's approach to VE design, where he proposes that the most recognizable aspects, and most dominant identity entities, are singular, mutually isolated landmarks. From the results in this project, it does not seem to be the case for nursing home residents. The single most mentioned 'content' between RVEs in Paper IV is 'the whole', or in other words, the perception of the location identity overshadowing the individual objects in the scene.

6.3. IMMERSIVE SYSTEM PROPERTIES

RQ3. *What is the relationship between the sense of presence inside a VE augmentation, and the level of motivation to exercise, for nursing home residents?*

- *PAPER V.* Intrinsic motivation increased only slightly following a noticeable increase in the sense of presence, from increasing the immersive system properties of the exercise augmentation with a HMD.

While results from both the SUS questionnaire and observations in Paper V showed high increases in the sense of presence following the introduction of the HMD to the augmentation setup, the effect on motivation (while increased) did not suggest a similar effect. The explanation might need to be attributed to the novelty of the experience, the sensory impact of the more immersive RVE experience, and the related complications affiliated with using the HMD. Comparing IMI item-based motivation results and the preference report towards the HMD as the exercise experience of choice, to the observations from the video footage of residents using the HMD, there seemed to be a discrepancy. Some residents, who reportedly did not prefer the HMD, were highly engaged in the experience while exercising, explicitly enjoying the experience and interestedly exploring the RVE afforded by the new orientation possibilities. Thus their choice of not preferring the HMD experience to the LCD TV, was contradicting their behavior. However, a possible contributing factor is that how their own choosing of preference was formulated in such a way, that their preference should be understood as continuing with the display of choice, and removing the option for the opposite display. Choosing the HMD would mean that the LCD TV would no longer be available. Considering the convenience and pleasantness of the LCD TV augmentation compared to the intense experience of the HMD, combined with the physical difficulties of many residents, this should be a factor to the result analysis as well. It suggests the importance of more studies on the complexities of the resident/HMD relationship.

RQ4. *What are the advantages and disadvantages of introducing highly immersive* *technologies into VE augmented manuped exercise for nursing home physical therapy?*

- *PAPER V*. Highly immersive technology (in this case, an HMD) is able to induce a high sense of presence, and allow convincing and positively impactful sensations of being at another place than the nursing home.

- *PAPER V.* Usage, orientation and wearing the HMD in this setup can be completely intuitive and natural for the older adult residents.

- *PAPER V.* Highly immersive technology (in this case, an HMD) might be too cognitively demanding for some residents.

- *PAPER V*. Highly immersive technology (in this case, an HMD) is likely to negatively affect the duration of physical exercise.

- *PAPER V*. Highly immersive technology (in this case, an HMD) is unsafe for everyday manuped exercise without assistance.

As already reported about RQ3, an HMD was able to increase the sense of presence noticeably for participants in Paper V, which was observed to impact participants' experience and (orientation based) interaction with the RVE while exercising. For many, this was a positive addition to the augmented exercise, and 5/9 preferred the HMD. This is impressive, considering a) their age, b) stagnant health, c) large physical/cognitive resource requirements when using the HMD, and d) that the study represented their first HMD experience. This might be attributed to residents reportedly finding the HMD very intuitive and natural to wear – when it was correctly placed on their head. Besides, their sense of naturalness might be attributed to the runtime optimization of the RVE. An effort was placed into having the RVE run a constant 75fps (frames per second – 75 being the maximum update frequency of the Oculus DK2), as internal testing suggested that the risk of VR sickness and discomfort would increase with lower frame rates.

However, as also suggested, the discrepancy between some users' positive behavior during observations and negative choice of HMD preference is interesting. In Paper V, exercise durations were only half as long with the HMD, as the average exercise duration for the individual resident, using the LCD TV. When removing the HMD from the head of participants, it was clear that they were exhausted. It was also clear that they were disoriented. Wearing an HMD can make any user lose complete 'connection' to their real world situation. The sensation can be compared to losing control over one's situation, in a perception of reality that feels 'warped' into an alternative state. This can be cognitively challenging to experience, and for already cognitive and physically challenged users, this experience might be amplified. It will need to be addressed in future studies, but it seemed that most participants were more affected by half the standard duration of HMD exercise than twice the duration with the LCD TV. This also suggests that while the HMD has a real potential concerning compelling experiences for nursing home residents, exercise augmentation, where residents need to be physically active as long as possible, might now be ideal.

Last but not least, there are safety issues connected to HMD implementation for nursing home residents. Besides the currect Oculus DK2 being too heavy, safety issues also relate to the sensation of loosing 'connection' with the real world situation. On several occasions during studies for Paper V, residents' heads needed to be pushed back (by me), as the hand-pedal arm would otherwise have struck them in the head. This happened because they lost the sensation of their real world position in space, from the dominant spatial stimuli of the HMD. This represents a very negative prospect for HMD-based manuped augmentation or augmentations to devices similar to the manuped. As described in Chapter 2, the essential role of the manuped for the physical therapy clinic is its ability to be used unassisted. Using a flat screen display, such as the LDC TV, keep the manuped exercise philosophy intact. Using an HMD for the augmentation requires assisting staff to be present and ready to intervene if the resident would lose understanding of place and position in the real world. As such, the LCD TV seems the most suitable baseline choice for a nursing home based augmentation, while the addition of the HMD could be an alternative solution, e.g. for individual sessions or afternoons with a minority of visitors at the clinic. However, in such case, it would seem likely that residents would prefer to have a conversation, rather than entering a virtual reality.

6.4. FUTURE PERSPECTIVES

From an academic perspective, the crux of this project revolves around older adults, virtual reality and exercise (/public health). Older adults will continue to be a priority for the world's societies for decades to come, which can be seen by large funded projects from H2020 , for example € 3.8 million for the FrailSafe project on understanding and preventing frailty, in collaboration with University of Patras. Physical fitness is also considered part of the H2020 scope, with the University of Bern awarded €6.4 million in funding from H20202, for cardiac rehabilitation research for older adults. Virtual reality has seen its final breakthrough as a commercial technology since Facebook purchased Oculus VR in 2014. This implies a vastly increased exposure, development of VR technologies, lower prices and higher quality. This is good news for the perspectives of combining VR rehabilitation with the nursing home context. Size, weight, and obtrusiveness of HMDs will be improved, while affordable. Research on VR, for instance, solutions to reduce VR sickness has surfaced recently [**117**] [**118**], and the trend is likely to continue.

The solution in this project is one of many possible. It was positively surprising to see the intuitiveness of residents with the Oculus DK2 HMD. And while it might not be perfectly suited for manuped exercise (despite the slight majority of residents preferring it to the LCD screen), it is my opinion that immersive VR has a potential to fulfill in relation to nursing homes. The combination of the homebound lifestyle, and the possibility to bring remote places to the user, is logical.

For augmenting exercise, results on the RVEs suggest that it is a good concept for nursing home residents. But more research is needed (with a higher quantity of participants) into the effects of RVE experiences and how the design can deliver the most effective restorative experience. Alternative ways of exploring sensory displays and increase the immersive system properties in unobtrusive forms are also attractive, which could potentially include considerations of cognitive or social aspects. The sparseness of literature, on the experiences that can motivate older adult residents to maintain a regular exercise routine as well as routines which support their cognitive abilities need very much to be addressed.

CHAPTER 7. LITERATURE LIST

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CHAPTER 8. PAPER I. AUGMENTED EXERCISE BIKING WITH VIRTUAL ENVIRONMENTS FOR ELDERLY USERS: A PRELIMINARY STUDY FOR RETIREMENT HOME PHYSICAL THERAPY

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ABSTRACT

Virtual reality (VR) has been shown to function well as an assistive technology to physical therapy for elderly users. Elderly users are a unique user group in this field, due to their characteristics and demands. They are also a user group that can definitely benefit from VR technology, which is unfortunately a perspective that seems elude the VR community. This study explores how augmenting a manuped exercise (chair-based exercise bike), using an interactive screen-based virtual environment (VE), can change the exercise experience for retirement home residents. It is the first study in a series of studies, initiating an investigation into how to use VR to augment conventional exercise experiences, specifically for the retirement home resident audience. In a larger scope, the ambition is long- term to use VR technology to increase motivation with retirement home residents, to uphold a regular exercise routine. The results showed that a majority of subjects reported to support the VE augmentation and preferred the VE based exercise experience to the conventional exercise. This supports VR as an assisting technology for physical therapy, and suggests the potentiality VE augmented exercises, tailored for retirement home residents.

KEYWORDS: Technology, Virtual Environments, Exercise, Assistive, Elderly, Augmentation

INDEX TERMS: [K.4.2: Social Issues Project]: Assistive technologies for persons with disabilities

1 INTRODUCTION

Many of us probably take our physical functionality for granted, and might not consider the central role it plays for a meaningful everyday living standard. Meanwhile, as we grow older, many biomechanical functions decay at a faster rate. Regular physical exercise will decrease the speed of such decay and allow the individual to retain physical independence for longer [1]. Physical therapy is therefore a central consideration at retirement homes. But despite daily, free access to professional physical therapy and knowledge of its clear physical benefits, many residents at retirement homes rarely or never partake in regular exercise. Meanwhile, it has been shown that VR technology has been able to work well for physical therapy in relation to rehabilitation [2] [3] [4], but most of these studies have been made with technology that, while applicable to elderly, is not designed specifically for elderly users. Retirement home residents can furthermore be considered an even more specifically demanding user group, due to their increased physical and mental limitations. The overall question for this study is to see if a virtual reality (VR) type augmentation of the manuped exercise shows any promise as an assistive technology for the retirement home residents, and if so; which. This study attempts to a) investigate whether the elderly residents can embrace VR technology as part of their exercise experience, and b) to highlight any central parts of such experience that could be developed further in future studies. The aim for this, along with future studies, is to eventually know enough about the relationship between residents, exercise and VR, to convert the negative approach to regular exercise into an inspiring exercise experience.

2 PRELIMINARY EVALUATION

At Akaciegården, a retirement home in Frederiksberg, Denmark, a qualitative study involving 16 residents showed that the most common reason (besides body pain) to avoid exercise is laziness and lack of interest in the exercise itself. It also showed that some of the exercise routines themselves are predominantly not considered compelling or stimulating. The exercise routine with by far the highest percentage of users at Akaciegården is the *manuped* – a regular chair-based exercise bike that uses both arms and legs to pedal (see: figure 1). It is often used, as it requires no balance and is thus considered one of the safer exercises. It is also flexible regarding the intensity of the exercise, relative to pedal resistance and pedaling speed. Especially its ability to provide low resistance exercise is important, as most residents are only barely strong enough to pedal with no resistance. For these reasons, the manuped is also one of the few exercise methods at Akaciegården that allow physical therapists to leave the residents to exercise without a need for constant supervision. The paradox of the manuped is that while being so broadly appealing and useful as an exercise platform, it is also one of the most static and repetitive forms of exercise at Akaciegården. This paper describes the effect on the repetitive exercise experience for a group of retirement home residents, when combining the manuped exercise routine with an interactive virtual environment (VE). As previously mentioned, retirement home residents require additional considerations as a user group, as physical and mental limitations intensifies the need for a different mindset, thus suggesting a need for specific tailoring when using e.g. a VE and VR technology in general.

3 BACKGROUND

Elderly are not often credited for technological enthusiasm, but according to Ijsselsteijn, et al. many elderly are in fact proponents of technology. But they need reasons and purpose, and don't want unnecessary learning processes [5]. The Nintendo Wii has been given much academic attention in relation to exercise and elderly. Positive results have been shown for elderly users in relation to increased physical activity [6] and rehabilitation in relation to balance treatment [4]. As an assistive technology, de Bruin, et al. point out the usefulness of gaming elements and virtual environments (VE) in the context of elderly and exercise using the dance-mat game *Dance Dance Revolution* for balance rehabilitation [2]. Siegert and Taylor discuss rehabilitation in relation to Deci and Ryan's self-determination model [7], and how achieving intrinsic motivation with rehabilitation subjects is central. Intrinsic motivation can be described as when the reward is internally/inherently interesting to the person and brings sense of competency and self-determination. This should afford a connection between subject and its exercise routines [8].

Holden and Todorov address how VEs are able to create a connection to the users actions through feedback, which is comparable to the real world. VEs allow independent exploration, and can create associations to real world experiences, in a world that is safe [3]. Interaction with a VE can relieve the retirement home resident from certain physical challenges they might normally face in the real world, and can even serve as a distracting layer, by moving attention away from e.g. pain occurring while exercising [2]. Meanwhile, a study by Laver, et al. specifically questions the Wii as a preferable method for rehabilitation/exercise therapy, opposed to conventional physical therapy [9]. The study was aimed at hospitalized elderly patients, which is an elderly user group very relatable to retirement home residents. Results showed that subjects believed conventional therapy to be preferable and more effective. The technology was simply not physically applicable to most, and did not meet the preferences within the user group. This was to the surprise of Laver et al., who original hypothesized that the Wii Fit would be the preferred method [9]. A study performed by Deutsch et al., measure the improvements in the fitness level of post-stroke patients (N=4) while using a custom built biking simulator (the "VRACK") including a VE augmentation. The VE uses a screen to display a 3rd person avatar biking along a non-playable character (NPC). The NPC is placed to inspire the user to increase the pace, depending on the heart rate of the user. Results showed significant increases in fitness levels over an eight-week training period [10].

The above-mentioned literature provides insight into the use of games and VR for rehabilitation purposes for elderly and medical patients, and the results are promising. Studies for overall digital interaction concerns, when designing for elderly, also provide insight [5]. Meanwhile, literature is sparse on the specific considerations (e.g. content and form), when it comes to tailoring inherently interesting digital or VR experiences for the elderly - a point that was also highlighted by Laver et al. [9]. Many rehabilitation studies that support VE augmented exercise focus on the physical effect of the VE augmentation, such as how Deutsch et al. show how their VE augmentation effectively increases the users' fitness level, but does not (in this specific study, at least) why it works [10].

4 MANUPED AUGMENTATION FOR RETIREMENT HOME RESIDENTS

VE augmented exercise could prove an interesting alternative to conventional exercise for retirement home residents. The limitations to their physical and mental capabilities can narrow their means to travel or otherwise experience new places, and result in a confined daily lifestyle. Using VE augmentations to aid the problem of exercise motivation might therefore fit this user group. VEs have the potential to provide a fraction of an experience, which is otherwise, mostly, no longer possible. A manuped/VE system was designed for implementation and placement in the physical therapy department at Akaciegården retirement home, to discover if resident users would embrace the technology and why they would possibly enjoy a manuped exercise with VE augmentation.

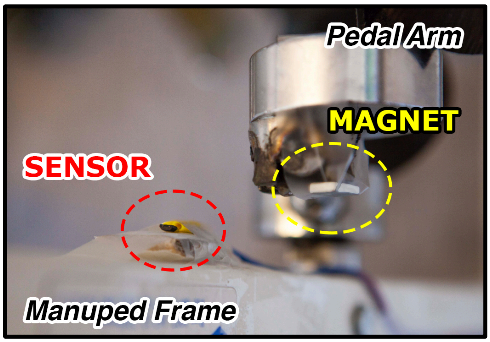

Figure 15 – Left: the manuped. Upper right: the sensor on the frame and the magnet on the pedal arm

Exercise platform. As previously described, the manuped was chosen as the platform of choice, due to its flexible exercise intensities, safety in use, but also repetitive exercise nature. The manuped is shown to the left in Figure 1. The platforms on the ground have a rubber surface, to keep e.g. a wheel chair in place when locked, during the exercise. Both arms and legs can be used to pedal.

Hardware. To track the user actions, a magnet and sensor was installed on respectively the pedal arm and frame of the manuped (see Figure 2, on the right hand side). The sensor was connected to an Arduino board and Macbook Pro via USB. The signal was processed through Max/MSP, which checked for signal changes every millisecond. The VE was displayed on a 1080p 46' Samsung LED monitor, running a relatively steady 40-50fps. The soundscape was played through a pair of Sennheiser HD600 headphones.

VE design and construction. An environment was created in Unity3d (see figure 2). Its specific environment and content direction was chosen on the basis of a qualitative study with 6 retirement home residents. Questions related the residents' preferences with real life environments that they had enjoyed experiencing. Results showed that a nature setting would be preferable. The VE was designed as a summer-time countryside and based on a trip along a gravel path going around a lake. Larger recognizable objects were trees, wooden houses and a large willow, along with additional smaller objects and environmental details such as grass. A simple soundscape was also added to support the visuals.

Figure 2 - The VE designed for the residents. A nature experience was the central requirement

VE interaction design. According to Smeddinck et al, interfacing and interacting with such technology needs to happen on a very simple level [11]. Initial trials at Akaciegården supported this, as simple real-time navigation with Wii Sports (bowling) proved too challenging for the residents. Laver et al. also address the importance of keeping the technology-interaction simple and relevant to the conventional exercise routines [9]. As a consequence, no additional interface interaction was added to the manuped, so the experience with the VE would correspond to their familiar motions. Just as importantly, the exercise routines given by the physical therapists would this way be maintained. The subject would move on a fixed path through the VE. The only interactive features was the choice of acceleration (to a limited top speed) or deceleration (to a halt) along the path. A constant top driving speed was chosen to normalize the traveling experience within the VE for both weaker and stronger subjects.

Acceleration and deceleration happened in 4 seconds and top speed had a calculated estimate of 8 km/h. These values were found by internal testing, and chosen based on a subjective opinion on what values (speeds) felt calm, but progressive. Top speed would be obtained with a pedal frequency of 1 second. This choice was made as this pedal frequency was observed to be the most frequently occurring pedal frequency among residents on the conventional manuped exercise.

5 USER STUDY

Participants. A group of 15 subjects were chosen by the physical therapists, who wanted to have the subject group represent different spectra relating to physical therapy. The performance level of the chosen subjects varied, both mentally and physically, but all subjects would be able to ride the manuped well. All subjects also knew the manuped, which was important for the study, as it would allow them to compare the experience of the regular manuped exercise with that of the VE augmentation. Only 10 subjects (2 male and 8 female) participated, as the rest declined on exercise day, due to illnesses. The age-span was of 66 to 97 years, with an average age of 83 (mean = 82.9, SD = 9.1).

Method. The data was collected based on an in-situ semi- structured interview. This was chosen due to considerations of a) the possible need for assistance during the exercise as a consequence of the mental limitations of some subjects, b) the need for explorative conversation at this early stage of the study, and the sensitivity needed for the individuality of user group.

Procedure. Before the session began, subjects were instructed to exercise as usual on the manuped but that they could stop whenever they wanted to. They were also introduced to the fact that they would be able to see a landscape on the screen in front of them while they were exercising, and told that they would be asked questions while they were pedalling. Subjects were given the freedom to only ride for as long as they wanted to, as opposed to their regular physical therapy, where each subjects normally had a specific pedal cycle count required. The reason for not forcing round counts on the subjects was due to pure curiosity to the length they would go out of free will. All interviews were video recorded, for analysis of the results.

Interview guide. Interviewing retirement home residents needs patience, and not all residents are able understand or give meaningful answers to seemingly simple questions or explanation tasks. As such, the semi-interview was pre-expected to be a conversation, with some main topics to cover. The majority of the interview was performed in-situ during an exercise session with the VE setup. In-situ was chosen due to the predominance of dementia among many retirement home residents. Some questions were however asked after the exercise session, to seek perspective upon the exercise experience. The whole interview guide (in-situ plus post session questions) contained 11 items. Earlier experience with conversation and interviews with the residents showed that only very simple questions would be possible, to ensure that the residents both understand, and was able to give correct feedback - a consideration also supported by Smeddinck, et al. [11].

Figure 3 - Subject exercising using the VE augmentation

The general aim of the questions was to get an overview of the subjects' experience of being exposed to the VE while exercising. If they connected to the VE and why, related to considerations from Holden and Todorov [3], and if it actually made them want to come back for more exercise in this form, indicating signs of intrinsic motivation to exercise with the VE augmentation [7]. Beyond that, indications as to general pros and cons of the VE design and role were also addressed. All items were thus designed for qualitative data, to increase the chance of useful information and chance of catching misinterpretations. Some items initially required closed yes/no answers, which would always be followed by the request of a qualitative elaboration.

The interview searched for opinions and statements from the residents, from four overall themes. Theme 1 had three items and addressed opinions of being exposed to the VE, for example "Would this be a place you would like to visit in real life? – Why/why not?"). Theme 2 had three items and focused on details about their exercise experience, for example: "Is there anything specific about this type of bike-ride that you like?". Theme 3 had two items and related to if they felt a connection between their exercise and the VE, for example "Do you have the sensation that it is you who is riding through this environment?". Theme 4 had three items and searched for implications about if such VE augmented exercise might increase their desire to exercise, for example "Which part of this experience should change, in order to make you want to exercise more?"

6 RESULTS

All subjects liked the VE, describing it as beautiful, fantastic, pretty, and lovely and green, due to the wonderful views, which were also (partly) the reasons why 8 subjects wanted to visit the VE if in real life. Other reasons were that the VE created various associations to experiences in their past *"(...) this reminds me of the place that my daughter was born."* Positive experiences with the VE exercise experience were the possibility for exploration, "*Simply being able to do as you please. (...) If I didn't have this, I could bike. But this makes is wonderful",* the "*opportunity to get away*" and observing the nature. The oldest (97 year old) subject described her experience as the sensation of "*biking through a painting*". One subject, who is almost unable to transport herself in real life, outside the retirement home, stated the following "(...) *the sudden ability to go outside and have the world moving towards you, in front of you, and the ability go places I've not gone before, seeing things I never knew. This is wonderful*". Another subject described that the VE provided a sense of accomplishment that she did not have with the conventional manuped exercise. 8 subjects had the sensation that it was them selves driving through the landscape of the VE. *"Something always happens before your eyes and you feel that it is you are driving that trip yourself".* 7 subjects believed this type of exercise could make them exercise regularly at the retirement home, and 6 subjects reported that it made them want to exercise more than usually. *"To sit in a regular gym is extremely boring and it needs to be made more interesting. This is good, and it provides a different experience".* Exploring the VE made the exercise less boring and provided energy and desire to keep going. *"I wanted to see what was around every corner. You got energy from watching the environment move pass you."* 4

subjects found the exercise experience to be less demanding than usual, and 3 subjects stated (while biking) that they would probably feel an eagerness to try again, once they were done exercising. 7 subjects stated that they would prefer the VE exercise to the conventional exercise. 3 preferred to circumvent it. One of these simply wanted to be left alone, to look out the window while biking and be in her own thoughts. She did not feel that this was possible with the VE. The two other subjects hated biking due to physical pain while doing so, and didn't feel that the VE made a positive difference. They generally wanted to not use the manuped altogether, if possible, and normally only exercised with the manuped, because they had agreed upon it with the physical therapists. 5 answered that the VE was perfect and no changes were needed.

Meanwhile, 3 subjects stated that the content of the VE didn't catch their interest. While they could appreciate the sort of beauty, it did not have a differentiating effect on them. 2 subjects also mentioned that redundancy would probably become an issue, once the environment had lost its initial novelty. One subject criticized what he perceived to be a lacking logical realism or function to the design of the small countryside community. *"The buildings do not tell me anything about where they belong or seem to have a functional sense. This environment is not built to be inhabited!"*. Constructive input from other subjects was that such thing (the VE) needed more things to explore, e.g. objects or places. It should feel more "alive", e.g. by including more movement of objects and elements such as trees, wind, water, etc. Objects themselves should inspire exploration and provide associations. An example of an object that drew attention was a large Willow placed in the middle of the VE, visible at most time by the lakeside. For objects the subjects remembered after the exercise, the willow was the dominant object, followed by (in order), houses, "normal" trees, the water (lake), grass, rocks, and nature in general. Suggestions to alternative environments were mostly a forest type environment or mountains like the Tour de France.

Time spent on the manuped for the VE ranged from 05m04s to 33m54s with an average of 14m29s (SD = 9m15s). The subjects drove between 243 and 1169 rounds during their participation (mean = 563, SD = 280).

7 DISCUSSION

The main interests of this study are to investigate whether it seems that retirement home residents could embrace a VE augmented exercise, to locate any central parts of their experience with the VE augmentation that could become focus areas for future studies, and try to ascertain if such exercise experience could inspire them to exercise more. Meanwhile, the small timeframe (14 to 34 minutes) spent per subject gathering data for this preliminary study means that the results must be taken only as an indication. This type of exercise augmentation will need to be tested through longitudinal studies.

Literature suggests that in order to have elderly consider technology it needs to be perceived as purposeful. And while adding the VE augmentation has a logical connection to the exercise, this did not ensure that residents would accept it. The results indicated that the VE did provide a sense of purpose, as the traveling experience through the VE provided a sensation of accomplishment from the exercise. This indicates a new sensation of competency (intrinsic motivation) that seems to be non-present with the regular manuped exercise. The VE augmentation was able to contribute several positive elements to the exercise experience, such as the (possibly also purpose-oriented) experience of moving while pedalling the manuped. The majority of the subjects felt that they were the ones biking in the VE, and expressed their enthusiasm about the actual sense of moving while exercising. The sensation of being able to “travel” to an unknown place was a positive contribution. Enthusiasm showed in the results by a curiosity to explore the VE. Meanwhile, it was not only the sense of moving that provided positive experiences, as subjects also stopped on occasion to embrace various views of the VE. In these cases, many expressed a sensation of beauty from the nature scene in front of them, and described their experience both from an overall impression of being in this “place”, as well as mentioning many of the individual objects in the VE as part of that overall experience. This indicates that both the overall mood and impression of the VE, and the individual, specific objects played an important part of the experience for the residents.

Based on these aspects, 7 subjects stated that they wanted to continue using the VE augmentation if possible and 6 subjects stated that the augmentation would make them want to exercise more than presently. These are positive results in relation to the VE content- and form orientation of this study, specifically for this user group and show signs of intrinsic motivation factors, as the VE augmentation did seem like an inherent reward related to the exercise. 3 subjects did not like the VE augmentation and did not support it. This indicates that such implementation might not be suitable for all. One subject simply wanted to look out the window and have complete peace of mind while exercising. Meanwhile, the remaining two subjects generally hated the manuped exercise in general, so it remains inconclusive if this result speaks specifically against the VE augmentation or remains an expression of dislike towards the exercise form itself. That 5 subjects stated that nothing should be changed leaves less material for further analysis or tests. Meanwhile, some did mention the possibility of a long-term, redundant experience, due to the small size of the VE. Given the preliminary VE design, with its limited size and complexity, a longitudinal exposure to this VE might not be able to provide a consistently satisfying experience. While e.g. the sense of moving will probably not degrade over time, other important experiences such as the curiosity to explore and the enthusiasm of e.g. beautiful views could fade in such a simple, static and small VE, as residents become more familiar over time.

Possible improvements could be the choice between multiple, larger and more diverse environment. The inclusion of more life and diversity into such future implementations would help to avoid the feeling that one subject expressed as “slightly static”. Other additions could be changes in weather, “dramatic” events occurring as the exercise progressed or the inclusion of NPCs such as animals.

A very interesting result came from the subject who was disengaged by a perceived lack of realism of the environment. He thought it to be unbelievable that people would be able to live there, in the houses placed by the road. In his opinion, the VE did not resemble a realistic setting for inhabitants, which turned the houses into objects that for him created disbelief. This is a very interesting point, and one that is definitely a worthy consideration for future instalments. It might be one of the aspects showing how this user group is unique, and possibly not as used to accepting fantastic media-made environments/designs as some other (e.g. younger) audiences.

This study differs from most of the other studies referenced in this paper, in the sense that most of these either focus on exercise/rehabilitation performance over exercise experience, or use technology to inspire exercise that was never originally intended specifically for elderly. The study also differs from all other papers referenced, by focusing on retirement home residents. This user group is a lot more challenged, both physically and mentally, than “regular” elderly users. This means that the need for specific solutions to inspire exercise is equally higher. Overall, the results must be considered encouraging for further studies. Combining retirement home residents with VR technology worked, as the majority of the residents embraced the VE technology and accepted the augmentation. The focus on the VE content design indicated solid potential as a tool to inspire regular exercise for elderly retirement home residents, with an exercise routine that is otherwise considered uninteresting. Many subjects had a truly enjoyable experience with the VE augmented manuped exercise and the majority wanted to keep exercising with this technology. Some of the statements quoted in section 6 show signs of real fundamental joy, especially compared to the attitude towards the conventional manuped exercise. And while it is an aspect that needs further and more rigorous testing to be validated, many of the user responses did show signs of intrinsic motivation with the subjects, relating to the inherent interest in the VE augmentation, and the sense of accomplishment which a sense of competency.

8 CONCLUSION

The results from the user study showed that it is possible for elderly users to be enthusiastic about VE technology, and that VEs can serve as impactful assistive technologies in relation to exercise, and physical therapy for retirement home residents. This study had the exercise routine of a manuped augmented, using a sunny countryside based virtual environment (VE). The majority of subjects enjoyed the addition of the VE, felt that their actions during the exercise connected well to the experience and behaviour of the VE, and had positive individual experiences with the technology – and therefore their exercise. They enjoyed being able to travel to an unknown place and the actual sense of moving while biking. They were curious to explore the environment and expressed their happiness with beautiful sights and feeling like being out in nature. 7 of 10 subjects believed that the technology improved the exercise experience and wanted to replace the conventional manuped exercise with the augmented version. 6 subjects reported that they would want to exercise more than they currently did, with this technology. Meanwhile, these results only serve as an indication, as more longitudinal studies are needed to give a more accurate impression of the benefits and potential weaknesses of this exercise encouragement method. Meanwhile, results definitely suggest that there is a lot of potential in this field, and that augmentation of the exercise routines using VEs might be a very effective method to motivate elderly users to perform regular exercise.

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CHAPTER 9. PAPER II. SIMULATING NATURE FOR ELDERLY USERS – A DESIGN APPROACH FOR RECREATIONAL VIRTUAL ENVIRONMENTS

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ABSTRACT

Recreational nature experiences are rehabilitative for humans. Nature-oriented virtual environments (VEs) might be able to provide similar experiences. A pilot study have shown to increase the enjoyment of an exercise experience for retirement home residents, by augmenting their everyday bike exercise with a custom made recreational VE. This paper proposed a set of guidelines with design considerations that should be considered essential when designing recreational VEs. The guidelines combine considerations from tourism, urban and landscape design, psychology and VE navigation guidelines.

KEYWORDS: Nursing home, Recreation, Rehabilitation, Virtual Environments, Design, Augmentation, Therapy, Guidelines, Elderly, Field Trip

I. INTRODUCTION

Virtual Environments (VEs) have been used for rehabilitation purposes for years, for example balance and stroke rehabilitation [1] [2]. VEs are able to provide a connection between real world actions and virtual world reactions, comparable to real world situations. They can provide safe testing environments for users who need a reality- like experience, with certain factors added, removed, or altered or under specific control in real time [3]. Virtually simulated situations can be tailored for untrained or incapable practitioners, as the VE simulation removes the real world consequences of inability or premature choices of action [4]. Augmentations through virtual technology can serve as a diversion, and redirect attention away from otherwise pain related exercises, relieving tension for example for elderly users during rehabilitation [5]. In a pilot study preceding this paper, Bruun-Pedersen et al. [6] showed how a simple VE augmentation of a manuped exercise was able to provide an improved experience over the conventional version of the exercise. The experience was recreational exploration of traveling along a trail in a nature-based environment. Results showed that 70% of the subjects wished to continue with the augmentation [6]. However, subjects also expressed a necessity for improvements to the VE design, in order to maintain interest for longer periods of exposure. Future implementations would need a variety of VE locations, with larger and more complex designs. This paper looks at interesting design considerations for recreational, trail- and nature based VEs to obtain useful design guidelines, and discusses it in reference to its application for elderly users.

II. BACKGROUND

From a psychological perspective, humans connect to nature surroundings and nature experiences [7]. Even through a window, nature-based stimuli produce relaxation and wellbeing [7]. Depledge, et al. [8] describe how humans have a health related link to nature. Nature experiences can reduce stress, recover attention capacity and cognitive functions. The authors suggest that high-fidelity VEs should be able to produce similar effects, especially through multimodal stimuli. This could prove useful with medical recreational purposes for elderly or hospitalized individuals [8]. Kort and Ijsselsteijn [9] use the term *restoration* to describe the same effects from natural environments. To promote physical activity with elderly users, consumer products such as the Nintendo Wii have been popular [10], but subsequently been questioned as dedicated physical therapy devices [11] [12]. The reason is, that serious physical therapy devices need to be tailored for unique user groups such as elderly users, also depending on the level of assistance available [13] [14]. At nursing homes, physical therapy must conform to how body strength, balance, flexibility, motor functions, and cognitive abilities are very limited with most residents. As a consequence, complexity, speed, strength and cognitive requirements for physical therapy must adapt accordingly.

A pilot study by Bruun-Pedersen et al. [6] tested the concept of augmenting an exercise action with a recreational trail-based VE exploration, for nursing home residents. Due to the limited abilities in both physical performance and interaction complexity of this user group, the interaction design was limited to the familiar movements of a conventional manuped exercise routine (pedaling with arms and legs). In the study, the VE experience consisted of a small trip around a lake, in a countryside environment. The goal of the pilot study

Figure 1 - Pilot Test in [6] used a countryside VE

was to test if the users would accept the augmentation, if the inclusion of a VE augmentation changed their exercise experience, and why. Results showed that the augmentation was able to contextualize the pedaling actions to the VE trail. The VE created a sensation of purpose to the exercise actions, by the sensation of moving forward and to experience travelling and exploring another place than the nursing home. The augmentation gave some subjects an experience of otherwise lost efficacy, by being able to "move themselves forward without assistance" from nursing home personal. Being exposed to nature-based "beauty" was given high praise, as the overall theme for the VE. It was clear that the augmentation resembled a recreational nature experience for many subjects. From the post-exercise interview, objects that had made a significant impression were the few houses and a large willow. Additional environment content such as trees, water and green grass, or features such as sunny day colors all supported the overall positive impression of the VE [6].

The level of fidelity of the VE's nature experience also showed indications to be sufficient (as most subjects thought the VE display to be authentic video footage), and overall, the continuation of the work was encouraged by 70% of subjects in the pilot study. However, results also showed a necessity for improvements to the overall VE design approach. There should be an increased diversity of VE content, with a stronger environment "identity", through a more accomplished consistency between types of trees, foliage, constructions, etc.). A larger variety of VE locations and more "life" (for instance animals, wind, running water) were encouraged, in order to increase enjoyment and curiosity with the users, in addition to sense of realism, surprise elements and thus longevity for the VE [6]. The pilot VE was built with little to no clear design method besides intuition and a few reference photos from Google, and depended on the availability of countryside oriented 3D assets for Unity3d. As such, the pilot study both suggested that a VE augmentation could work for this purpose, for this user group, as a recreational experience focusing on the wonderful potential of nature experiences. But also that very close attention should be placed on the design of the VE, due to its role as the main contributor of content for the overall experience.

A. Content necessary for recreation VE

In many studies on VE rehabilitation, the VE simply provides ambience for a primary task in close proximity to the user in the VE, such as often the case for mini-games or task solving for motor rehabilitation, often with no need for ecological considerations to the design [15] [16] [17]. Closer related are behavioral studies focusing on real world environment replication into VR [3] [18] [19], where the VE is the main communicator of information and has to be convincingly rigorous in its inherent content, structure and detail to produce a convincing experience. In the VE exercises from Nurkkala, et al. [19], some of the VEs are replica and some are custom, but despite the VEs being the main attraction of the installation, the paper presents no reasoning behind the requirements to the individual VE design. Lange [20] describes the development of detailed 3D environments as labor- intensive, and discusses where the perceptual limits could be,

to get the best realism-to-workload ratio. VE replications from real world environments require documentation (i.e. often requiring travel), detailed mapping and 3D modeling, etc. [*3*]. However, VEs based on real locations have the major advantage of already being fully designed, and thus being ecologically "perfect". Custom VEs are initially blank canvasses by comparison, and should be designed with knowledge of which criteria are relevant to be a convincing experience. Kort and Ijsselsteijn [9] suggest that multimodal VEs do not need photorealism to achieve convincing realism, due to top-down cognitive processes involved where vision only plays a part in a convincing realistic experience [9]. Lange [20] quotes Hall [21] concerning how correct imagery and geometric detail are not direct requirements for the impression of realism, as long as the behavior is reasonable. High image complexity and subtle shading and surface detail are central when creating the perception of realism [21].

Depledge, et al. [8] insist that *content* is a most critical issue, for ensuring engaging and immersive properties of a VE. For recreation-purpose VEs, exposure to water and forests visuals and outdoor environmental sounds should be considered, along with natural colors such as greens, blues and browns. Sounds from birds, water and wind, odors and air movement all contribute to this as well, with *water* being especially important. However, the presence of other human beings might ruin the effect [8]. Koenig, et al. describe their requirements for ensuring the recognizability of their real world office environment replication in that it requires enough environment details (furniture, etc.), high quality textures (to aid orientation), correct scaling of objects and realistic lightning. To ensure this, documentation through media of similar environments remain a valid way to analyze and find key identity elements for realism characteristics [*20*].

For nature experiences, Dorwart, et al. [22] examine the perceptions and preferences of visitors of Great Smoky Mountains National Park trail based recreation tours, proposing a model for evaluating the nature-based recreational experiences [22]. The "Nature-Based Recreation Experiences" model include five themes of trail environment elements, where three *nature-oriented detail, scenic values, management influences* and *depreciative behavior* are related to the representation of the natural environment, an *presence of others* relate to the presence of other people in the environment [22]. For the National Park, *nature-oriented details* is the dominant theme, with positive reports on the appreciation of small details, for instance from plants and a green carpet of such vegetation, wildlife, to be surrounded by vast forest, rock- formations, and generally combinations of natural elements. Positive *scenic values* include high altitude vistas, overviews of trees and scenery, beautiful views, and light and shade combination. *Management influences* refer to maintenance of e.g. stairs, shelters, and other constructed elements to help the experience of nature. *Presence of others* relates to sharing the experience, and *depreciative behavior* is when people are not respecting the environment by leaving litter, trash, destruction, etc.) [22]. The trail itself need to blend in with the natural setting to keep the trail visually compatible to the surrounding environment, and curve if attention needs to be placed on the trail itself or trail elements. Other points of interest are beautiful vistas and natural elements, such as waterfalls. However, Dorwart, et al. [22] do stress how such results are heavily influenced by the individual's perception, preference and experience of each subject.

B. Navigation Guidelines to manage content

According to Vinson, content structure through a classification of distinctive environmental features, affords navigation proficiency through both large-scale real and virtual environments [23]. It's a reference point placement design framework, which is mostly oriented towards aiding a user's overview while navigating freely in a VE. It is meant to maximize recognizability, the user's sense of position in the VE and develop the user's mental representation of the VE. In a trail-based VE exploration design, where an exciting experience might be based on the element of surprise, Vinson's framework might seem contradictory. Meanwhile, the pleasantry of the exploration experience should come from the presence of interesting and pleasing content, and placing it cleverly does not automatically make it repetitive. Reference points, generally referred to as *landmarks*, ease the cognitive load and free resources for other perceptions or decisions while traveling a VE. An increase in recognizability of different VE locations could serve the memorability of the VE experience for nursing home users, who often suffer from a degree of dementia. Any user's knowledge of the VE is likely to have distortions. Landmarks minimize the risk of such distortions, and VEs should strive to contain several.

Landmarks are objects distinct from "virtual objects", which is what Vinson calls all landscape features and content [23]. Landmarks aid the user's interpretation of how to navigate the VE, through their distinction from virtual objects. Different types of landmarks serve individual purposes; *paths* (such as streets, canals) are channels for movement, *edges* (fences, rivers, etc.) indicate district boundaries, *districts* (neighborhoods) are reference points, *nodes* (town square, public buildings, etc.) are destinations for travel, and *landmarks* (such as statues) are reference points impenetrable for travel [23]. Individual landmarks need to be sufficiently distinct and unambiguous to make them uniquely memorable through detail variations such as height, shape, etc. and ensure that they are distinguishable from their surroundings [23]. Man-made landmarks are easily remembered, while virtual objects are less reliable. Landmarks should be considered in all viewable sizes in the VE, for different layers of VE position reference from a viewing distance. Landmarks should be placed along major paths and in junctions, as these provide identity to the landmark (and therefore place on the path). There should be a balance to landmark placement, and ideally two landmarks should be visible at any time. To ensure a spatial relationship between individual landmarks, these should ideally be structured in a top-view map overview. Vinson [23] recommends that paths resemble a *grid* (for navigation overview). But for recreational VEs, a grid based forest path could be argued to remove the nature-based organic sensation. All in all, the approach of the landmark typeset is a valuable combination of a top-down and bottom-up design approach.

III. METHOD: RECREATIONAL VE DESIGN GUIDELINES

From the reviews in the previous section, we found many relevant considerations for recreational VEs, ranging from quite specific items, to technical considerations, to broad recommendations or guidelines. In this section, we propose some *Recreational VE Design Guidelines* in which we organize the review findings into two central categorizations; *Recreational VE Content* and *Recreational VE Features*. During this section, we will regard several considerations about recreational VE design from these main categories, whose main purpose is to structure and increase clarity on how to approach specific necessary characteristics of a recreational VE. We chose to present the two categorizations in relation to their useful application within the typeset of *landmarks,* and how some aspects of the categorizations play an important role outside of the landmark typeset. The chapter presents two pairs of tables, each pair representing one of the two main categories, split into considerations applicable to a) the landmarks typeset and b) other relevant factors found in literature.

Before addressing the tables concretely, it needs to be said that they retain a generalist approach to their message, in the sense that they don't target a specific VE design. Therefore, when e.g. types of content are represented, it leaves it up to the individual design team to determine the specifics of what constitutes the appropriate and specific items to represent the individual VE's core identity. In other words, a mountain VE would contain different natural items than a tropical jungle, etc.

In terms of how the tables are set up, they place heavy focus on the *landmarks* typeset. The motivation for this lies in the previously explained ability of landmarks to provide a structural approach to placement of VE content. Landmarks should be considered useful allies in any VE design, in terms of their ability to increase a designer's understanding a VE's individual parts, and in turn increase the probability of the user's ability to recognize the individual areas of the VE. The *Recreational VE Content* (as shown in Table 1) outlines the parts within the recreational approaches in the literature review that fits within Vinson's definition of the landmark types.

Common for the *Recreational VE Content* representing each landmark type in Table 1, it's mostly represented by various human type influences to a landscape. Landmarks should predominantly be man-made. In a nature environment, it makes them stand out, but in addition, man-made objects do not rapidly change appearance like many natural objects (bending, wind, growth, decay, or other inconsistencies in appearance). While this is sensible, most work reviewed in this paper finds essential VE content for recreation to be are nature oriented and non-human based, with a common emphasis on how man-made objects should be kept to a minimum or at least be well maintained. In that sense, Table 1 shows only VE content found that fits into the prescriptions from Vinson [23].

Table 2 shows recreational VE content found from non-landmark content represented in the review literature. Vinson [23] uses the term *Virtual Objects* for landscape content items of the VE that are not landmarks. This category holds many of the literature findings deemed to be recreational VE content. Different from what Vinson focuses on in his use of landmarks as navigation tools, for recreation, Virtual Objects are environment content that defines much of the VE identity, by forming the backbone to the otherwise useful landmarks. For recreational purposes, the reviewed literature shows that virtual objects hold a lot of the value of the recreational experience. Landmarks should be remarkable, and definitely able to be defining parts of the VE experience, but without the virtual objects, the landmarks would be "naked" objects without context. Therefore, virtual objects are both very necessary as supporting content for the individuality of the landmarks, but also represent much of the essential recreational VE content.

The same type of VE content can represent different types of landmarks and vice versa, by the role it plays in the VE, as for instance shown through which type of landmark the given content represents in a given situation. A "trail" can be a path, but it can also represent an edge. It can be part of a node's functionality (for example giving an view of many trails in the distance), but at a later point, the user might be positioned in the spot that previously represented the view given by the node.

Table 1 - Overall considerations for content types that literature suggest for recreation, which fits the individual landmark types.

Landmark Types	**Examples of Recreational VE Content**
Path	Trail [6, 22, 23] Man-made objects [23] Maintained human objects [22]
Edge	Water [6, 8] Trail [6, 22, 23] Man-made objects [23]
Node	Houses [6, 23] Public/official structures or spaces [23] Man-made objects [23] Maintained human objects [23] Waterfalls [22]
Landmark	Man-made objects [23] Maintained human constructions [23] Waterfalls [22] Statues, monuments etc. [12]
Junction	Trail [6, 22, 23] Man-made objects [23]
District	Specific combinations of virtual objects and landmarks [23] Neighborhoods 9 [23]

Table 2 - Overall considerations for content types that literature suggest for recreation, ranging outside conventional landmark types

Non-landmark Items	**Examples of Recreational VE Content**
Virtual Objects	"Green carpet of vegetation" [22] Grass, plants, trees, "greens" [6, 22] No litter, etc. [22]
"Life"	Running water [6, 23] Wildlife [6, 22] Air movements [8] Outdoor environmental sounds (air, birds, water, wind, etc.) [8] No humans [8, 22]

Trail-based, recreational VE designs need high diversity in the VE content, and often have numerous objects combined to a larger whole. An overall consistency, with a consciously set of content items is important, to create and maintain an environments' identity. Varied documentation (photos, video, etc.) is central for ensuring such identity. Rich surface and geometric detail, as well as high quality textures add important visual fidelity, and high environmental complexity in various forms is a priority, in micro and macro perspectives. This signifies well what Table 3 and Table 4 represent, as the features that should be considered for the content represented in a recreational VE.

Table 3 - Features that given landmark types should accommodate.

Landmark Types	Examples of Recreational VE Features
Path	Surface detail [22] Small details [22] Blending into the VE [22] Nature-based surface [22] High quality textures [18]
Edge	Surface detail [22] Small details [22] Blending into the VE [22] Nature-based surface [22] High quality textures [18]
Node	Visual consistency between elements [6, 18, 22] High altitude vistas [22] Beautiful vistas [8, 22] Overview of parts of VE [22] Depth cues [22]
Landmark	Variations in height, size, form [23] Surface detail [22] High quality textures [18]
Junction	Surface detail [22] Small details [22] Nature-based surface [22] Blending into the VE [22] High quality textures [18]
District	Visual consistency between elements [6, 18, 22] Nature [6, 7, 8, 9, 22] Forest visuals [6,8, 22] Water [6, 8] “Green carpet of vegetation” [22]

Table 4 - Features that non-landmark type content should represent.

Non-landmark Items	Examples of Recreational VE Features
Virtual Objects	Visual consistency between elements [6, 18, 22] Natural colors [8] Surface detail [22] Small details [22] Reasonable behavior [20, 21] High quality textured [18] Correct scaling [23]
Other considerations	Varm lighting [6] Subtle shading [20, 21] Realistic lighting [18] Light/shade combinations [22] Multimodal display [6, 9] High image complexity [18]

So while the *Recreational VE Content* relates to the types of objects to place, the *Recreational VE Features* relate to how either technical or artistic qualities play a large role in the presentation of the VE content, landmark or non-landmark. As a large-scale VE should be based on several *districts*, each individual district should have unique characteristics. Many of these are found through the Recreational VE Features, from a degree of variance between landmarks and virtual objects (along with the "life" factor). This forms the chosen identity of the district, as well as (districts collectively) the VE. On a different perspective, each of these entries in the VE has unique roles to play, according to the perspective of use in a given situations. *Nodes* for instance, grant possibly beautiful vistas is important for trail-based VEs, creates a sense of scale as *depth cues* to both near and far VE elements, and possibly even give hint to several other *districts*, which for instance was a central experience of a mountain-based environment [22]. It is here that the landmark-oriented approach is well used as a mapping approach. A depth-enhancing *node* as a beautiful vista can be planned very easily, and ensure that it plays well together with other landmarks, as well as the virtual objects, etc., also for its role as a recreational feature of the environment. Such angles open the designer to a creative approach within a specific terminology-based rule-set, either in a top-down or bottom-up process, depending on the phase of the design. A top-down approach should prove beneficial in the initial planning stages of the VE, as well as any mapping and overview processes. A bottom-up approach should prove useful when testing the role of already placed VE content, relative to their landmark type and role. The use of a *grid* to form paths and outline districts in a simple form, to reduce distortion is recommended by Vinson [23]. While block-like path grids are an obvious representation of natural environments, the idea of using a grid to overlay a VE map top-down, should be a more systemic way to balance the distribution of landmarks, as well as identify their individual roles.

IV. DISCUSSION

This paper proposes an overview of considerations to form a set of guidelines for creating custom-built VE designs. The background review takes its reference in many different areas, ranging from VE designs that copy real world environments, to results from tourism, based on user experience preference data derived from real world recreational trail hikes. The paper also shows how some attempts to make custom built VEs seem to have been made without a clear design approach, which leaves the question of whether a higher quality VE could have been obtained, had they been given a structured design approach. Depledge, et at. [8] state that content is essential, but it's hard to neglect the relevance of how such content is constructively placed or functionally positioned in an environment, especially considering VEs that are not 100% based on real environments references. To use the landmark typeset from Vinson [23] and apply them usefully but in a slightly different role, is an interesting exercise in using the merits of something, with an alternative application purpose.

Besides the alternative view on the relevance of landmarks, the way these Recreational VE Design Guidelines propose a separation into categories of (recreational) *VE Content* and *VE Features* is another way of proposing the necessity of looking at VE design in a multifaceted fashion. That a specific content type is relevant in a specific VE is a good entry-point, but the representation of this content is something that should vary depending on the purpose of the overall expression of the VE design. For recreation purposes, literature speaks a clear language in terms of how the recreational content needs a distinctive amount of detail, realism of lighting and complexity in its composition, to create due to its purpose of being inherently interesting in itself.

However, much of this depends on the user group who is to receive the experience. In this paper, the guidelines have taken in references from the pilot study from Bruun-Pedersen, et al. [6] to affect the content and feature guidelines of a recreational VE. From the study, it was evident that the concept had merits, but future studies will need to concretely examine more about the specifics of their preferences. This should eventually provide an expansion to the current understanding of this user group and its preferences in relation to the correct use of the medium.

An interesting aspect to the content of this paper is the degree of interpretation that can be placed on whether landmarks should in fact only be man-made to be easily recognized and memorable. As Vinson seems to address urban settings more than nature-based settings, significant natural content *could* serve as landmarks, if sufficiently distinct as an object, sufficient in size and appearance, and significantly noticeable from their surroundings. This indicates that it is up to the individual designer or design team to evaluate whether a landmark fits into the overall identity of the VE, what the landmark expresses and whether it will work for its intended purposes. In this sense, the division in the guidelines proposed in this paper, between the landmark typeset and the other factors such as virtual objects, "life", etc., might open this discussion even further, once the guidelines are being put to concrete use in a future study.

This obviously leads to future works, where concrete examples of VE designs will give an impression on how to practically take the design guidelines into convincing custom made VE location. To further expand on the guidelines, more detailed considerations from game level design research, as creating multimodal expression and environmental experiences for the general public should be considered. Fields such as scenic beauty research and aesthetics research could prove very useful. Even so, the fields, which are in fact, addressed in the paper such as restoration, recreational tourism, urban design, urban planning, cognitive psychology and landmark research spans much further than what has been addressed in this paper. Going forward, more work on these recreational VE designs should address issues such as these. Meanwhile, the current proposition of the Recreational VE Guidelines in this paper seems like a step in an interesting direction for this relatively novel field.

V. CONCLUSION

In this paper, we are proposing what will most probably only be the beginning of the *Recreational VE Design Guidelines*; a set of considerations and approaches found relevant when building custom VEs for recreational purposes - in this case, for elderly users at nursing homes to augment a biking exercise. The guidelines are built from a literature review of relevant studies from different fields spanning recreational real world environments, VE design, and a landmark typeset originally used to facilitate effective navigation in VEs. For future works, the framework will facilitate the development of recreational VEs for nursing home users, who suffer from decreased memory capabilities. The guidelines need more research and testing, but the considerations seem useful.

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CHAPTER 10. PAPER III. MOTIVATING ELDERLY TO EXERCISE – RECREATIONAL VIRTUAL ENVIRONMENT FOR INDOOR BIKING

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ABSTRACT

For most nursing home residents, regular physical exercise is a necessity to keep standard motor-function and strength. Meanwhile, many nursing home residents do not pursue this actively. This paper examines if augmenting a conventional chair-based bike exercise, with a suite of four recreational virtual environments, will increase the intrinsic motivation with a group of nursing home residents. After 4-months of availability, results suggest that the augmentation has increased the intrinsic motivation to exercise, by comparing results from before and after, using measurement scales from the Intrinsic Motivation Inventory.

KEYWORDS: intrinsic motivation; nursing home residents; elderly; virtual environments; augmentation; exercise; indoor bike

I. INTRODUCTION

At old adulthood, the muscle mass of the human body decays at a much more rapid rate [1], so maintaining physical activity is essential at high age, and neglect will result in deficiencies with a broad effect on everyday living [2]. Examples of this could be difficulties walking, getting dressed or even lifting one's own glass unassisted. In many nursing homes in Denmark, in-house physical therapy is offered as part of the daily exercise possibilities for residents. At the 'Akaciegården' nursing home in Copenhagen, one of the essential exercise methods for the nursing home physical therapy is a manuped; a chair-based bike device (see Fig. 1.). It is an essential exercise tool, as it activates both arms and legs and can work with a high variance of intensity. It neither requires active balancing, making it safe to leave a resident unassisted while active with the device.

For physical therapy, which residents are recommended to attend, and the short and long-term physical benefits are discussed with the physical therapy personnel. But for a large group of residents, the knowledge of the health maintenance benefits of exercise is not sufficient to motivate the maintenance of a regular exercise routine [3]. In a pilot-study by Bruun-Pedersen, Pedersen, Serafin and Kofoed [3], interview findings showed that while residents really liked the physical therapy milieu, the manuped activity itself (the primary part of a physical therapy routine for most) was considered trivial and generally uninteresting. For these residents, interview findings suggested that the exercise activity itself should contain an attractive factor, to motivate participation [3]. In an attempt to achieve this, the pilot study introduced a group of residents to an augmentation of the manuped exercise, by pairing it with an audiovisual recreational virtual environment (VE). When pedaling the manuped, the VE simulate the user moving forward along a fixed path. Subjects tried the augmented exercise once, while being interviewed in-situ. Findings showed positive indications that a recreational VE augmentation could motivate subjects to exercise more than before. It also inclined more expansive studies on the effects of such augmentation design on e.g. motivation to exercise, the mediation technology and more elaborate VE designs. Findings suggested important improvements to the VE design, to maintain user interest for subjects exposed to the augmentation for longer periods, which lead to a review of the design approach for recreational VEs [4].

Figure 1 - The manuped and chair, used for physical therapy bike exercising at Akaciegården nursing home

In this paper, we expand upon the experiences from our pilot-study into a 4-month longitudinal study, to measure the effects on intrinsic motivation to exercise for a group of nursing home residents, using an improved and expanded implementation of a recreational VE augmentation for the manuped device.

II. BACKGROUND

"You can lead a horse to water, but you can't make it drink" is a well-known phrase used to place attention on the importance of the personal, free choice of others. Despite all the good that exercise could do for nursing home residents, the nursing home cannot enforce routines. Based on before mentioned interview findings, many residents based their decline from physical exercise on how they did not like the manuped exercise activity itself [3]. For this reason, the manuped augmentation is meant to contribute an enjoyable layer to the exercise, which will alter the perception of the exercise, and contribute a necessary aspect to the routine that residents will find inherently motivational.

A. Intrinsic Motivation and Self-Determination

"*Perhaps no single phenomenon reflects the positive potential of human nature as much as intrinsic motivation, the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore and to learn*" [5]

According to American psychologists Ryan and Deci, to be motivated means to be moved to perform an action [6]. People who are energized or activated towards an activity should thus be characterized as motivated. People who feel no inspiration or impulse to act would accordingly be characterized as unmotivated [6]. The value of motivation according to Ryan and Deci, ties to how it is able to produce action, increase creativity and learning, enhance performance and persistence, as well as heighten self-esteem and general wellbeing [5].

Self-Determination Theory (SDT) is a theoretical framework based on the assumption that human nature, in its fullest representation, is inherently active, inquisitive and self- motivated, and without the need for additional external reward [6] [5] [7]. The SDT perspective on motivation is considered multidimensional, as its considerations concern itself with both the level of motivation and the orientation (or type). One of SDTs most fundamental distinctions lies between intrinsic motivation (when performing an action because it is inherently interesting or enjoyable) and extrinsic motivation (when performing an action because it leads to a contingent outcome that lies outside of the action itself) [6] [8]. Both are necessary for SDT to explain the nature of the motivation phenomenon and its orientations [6] [7]. SDT argues that self-determined motivation stems from (and depends on) three universal human psychological needs; autonomy (self-determination; to be the causal agent of one's own life, to give one-self one's own law), competence (self-efficacy; the perceived belief in one's ability) and relatedness (shared experiences and/or meaningful relationships) [6] [9]. SDT believes that humans are prone to react to these needs, which is why Ryan and Deci do not believe that motivation is caused, but catalyzed. Motivation is thereby either facilitated or undermined by situations or environmental factors for any given individual [6].

SDT has several subtheories in its framework. Primarily addressing intrinsic motivation is Cognitive Evaluation Theory (CET) by Deci and Ryan [7]. CET focuses on the psychological needs for autonomy and competence in a social context. Feelings of competence can enhance intrinsic motivation through e.g. optimal challenges, effectance promoting/positive feedback, and freedom from demanding evaluations [6]. Conversely, tangible rewards, threats, deadlines, directives, competition pressure, negative feedback, and contingency on task performance undermine intrinsic motivation [6] [5]. Meanwhile, the perception of competence (self-efficacy) will not increase intrinsic motivation without a sense of autonomy [6]. Autonomy (self-determination), as opposed to external control, is a must if an individual is to feel, maintain or enhance intrinsic motivation [6]. CET principles are only applicable to activities that hold some intrinsic interest for the individual, why SDT encompasses several additional subtheories; Organismic Integration Theory (OIT) [5], Causality Orientations Theory (COT) [7], Basic Psychological Needs Theory (BPNT) [10], Goal Contents Theory (GCT) [11], and Relationships Motivation Theory (RMT) [12].

In this paper, we will only focus on CET and intrinsic motivation. Brunet and Sabiston [13] conclude how "Identifying factors that influence intrinsic motivation and identified regulation for physical activity within each age segment is necessary to develop interventions to increase physical activity behavior across the lifespan" [13]. Our interview findings suggested that the long-term health benefits of physical exercise were not internalized by residents, and remained insufficient as motivation factors for many residents [3], so correct motivational factors remain to be identified and introduced to the exercise. Finch [14] do describe how the age group around 60+ generally wants to exercise for physical capability to maintain independence, avoid isolation and loneliness, and not be a burden to their family. Left unaccounted by Finch is how the foundation for these motivation factors has already surpassed for nursing home residents. Residents reside at nursing homes because they are incapable of independent living. The individual resident will no longer have to worry about functional dependency on family, but also accept the freedom/isolation degree of the nursing home. In the search for motivation factors, O'Conner and Vallerand [15] show how nursing home residents indeed recognize autonomous situations in their daily activities. Dacey, Baltzell and Zaichkowsky suggest that increases in intrinsic motivation can increase physical activity with elderly users, and describe SDT as "appropriate framework for studying physical activity motivation in this age-group" [16].

B. Intrinsic Motivation Inventory (IMI)

The Intrinsic Motivation Inventory (IMI)[7] is a measurement instrument developed by (at least) Ryan, Deci, Mims, Koestner, Connell, Plant, McAuley, Duncan, Tammen, Schwartz, Sheinman, Ehgari, Patrick, Leone [17] [18] [19] [20] [21] [22]. Its primary purpose is for laboratory experiments but can be used outside the controlled environment. IMI seeks access to individuals' subjective experience of an activity, after said activity has taken place. IMI measures the level of intrinsic motivation from a set of seven factors/subscales; The Interest/Enjoyment subscale is considered the self-report measure of intrinsic motivation. Subscales perceived choice and perceived competence are considered positive predictors of intrinsic motivation, whereas pressure/tension is a negative predictor of intrinsic motivation. Value/usefulness is a positive predictor of internalization (regulating the perceived value of an activity) and effort/importance is used to measure the activity's relevance to the subject. Relatedness measures the social connection to other entities or individuals.

The subscales contain 45 items between them and are all evaluated by scales from 1 to 7, where 1 is "not true at all", 4 corresponds to "somewhat true" (neutral) and 7 represents "very true". Items can be chosen and combined as seen fit, as many items overlap to some degree. Questionnaires can go as low as 4 items per subscale with no significant degrade to the factor validity. Generic items are allowed slight alteration to fit the context more clearly (such as exchanging the word 'activity' with 'swimming'). In a final questionnaire, the order of items is randomized. When scoring results, response scores in items representing the same factor are averaged and then used in the analysis of the relevant question. As will be presented later, a collection of IMI items from 5 subscales was used in this study, to evaluate the intrinsic motivation with subjects using the augmented exercise.

C. Nursing home residents, technological augmentations and motivation

The (early) augmented experience of traveling through a nature-based VE landscape was received well during the pilot- study, despite the lack of interest in the conventional manuped exercise [3]. For the majority of residents, seeing other places than the nursing home is no trivial thing, as many are in fact living an isolated, dependent life as was mentioned by Finch to be the very thing that 60+ year olds had stated to try to avoid by exercising [14]. Perhaps thereby, the experience of exploring the VE seemed (intrinsically) interesting for most subjects. Among positive notions, the pilot-study results also suggested that the sensation of self-efficacy was enhanced by the augmentation, by the perception of being able to experience oneself moving forward independently [3].

[7] www. http://www.selfdeterminationtheory.org/intrinsic-motivation- inventory/

Such results need to be challenged by longitudinal studies, but as a technology, VEs seem to have potential as a tool for rehabilitation [23] and training of skills [24], due to its potential to mimic many aspects of real world situations [25]. On the condition that the environment delivers the premise, VEs have the potential to serve as a "virtual catalyst" to trigger that motivation, following the SDT assumption that humans are inherently active, inquisitive and self-motivated behavior, [5]. Ijsselsteijn, Nap and de Kort points out that elderly are even proponents of technology, as long as it serves an understandable purpose [26]. The application flexibility of VEs as a technology should represent a suitable variety of premises for motivation (to exercise), if it meets suitable identifying factors for the age group to influence intrinsic motivation for physical activity [13]. For nursing home applications, VEs then allow an experience of travel or independent exploration that would otherwise be impossible in the real world - either due to mental or physical limitations - while in a safe environment [23].

In preparing for a longitudinal study, factors that positively influence intrinsic motivation were indicated in the findings of the pilot study, by the recreational aspects to the exercise experience. In more detail, the importance of overall scenic beauty, significant content that caught the eye (such as unique objects of trees, rocks, water, among other objects), and the already mentioned concept of being able to move and travel a landscape were prominent findings [3]. Improvements such as more content diversity, more "life" (animals, dynamic environment behavior), larger areas to explore and a variety of VEs to choose from, and a stronger VE identity were stated to be necessary, for interest in the VE experience to be kept for prolonged exposures [3].

D. Recreational VE Design

In a literature review subsequent to the previously described pilot study, Bruun-Pedersen, Pedersen, Serafin and Kofoed [4] examined the field of recreational, nature-based VE design for trail-based exploration. From a general lack of all-encompassing literature, the review retrieves its background knowledge from a range of fields, such as tourism, urban design, landscape design, psychology, VE simulation of real world environments, and VE navigation guidelines. The result of the review is the proposition of a set of Recreational VE Design Guidelines (RVDG), which have been used to guide the design of the four VEs used for this study. The main purpose of these design guidelines is to help the VE designer increase clarity on how to approach and structure specific, and necessary characteristics of a recreational exploration experience along a fixed trail. The guidelines suggest various types of recreational content, and how the VE designer can purposefully create unique and easily recognizable local areas in the VE.

The RVDG organizes findings into two main categorizations; recreational VE content (objects or spaces found important for a recreational experience) and recreational VE features (characteristics important to the VE content, such as surface detail of objects, or depth cues of spaces). Within both categorizations, most items are structured according to a landmark typeset (paths, edges, nodes, landmarks, junctions and districts), inspired directly by already established design guidelines to support navigation in VEs, by Vinson [27]. Vinson's guidelines do at least two things; it forms a design approach for the placement of items in a VE, from a specific landmark typeset, which includes singular objects (paths, landmarks) or areas e.g. combining objects (nodes or districts). The landmarks also afford easy recognition of the VE layout for the user, by various points and levels of reference for the user (size, distance and orientation) [27].

In RVDG, the landmark typeset is intended a similar use, but has landmarks types linked specifically to recreational content and features found in literature. For example, an edge type landmark can content-wise be anything from water, a nature trail, a man-made object (such as a fence), etc. In RVDG, feature examples for the edge landmarks include small details, surface details or high quality textures. But as high- fidelity VEs take a lot of computation, corners should be cut for processing purposes when possible. As the RVDG was created with a "fixed-trail exploration design" in mind (as opposed to "free roam"), the designer always knows the possible positions of the user in the VE, and should consider the role of the feature of the landmark accordingly.

For example, whether an edge should have high levels of detail or not according to the closest possible proximity in which the user position is expected to experience it. If a fence will never be in close proximity, it might simply be used to represent a distant trail or outline a district in a scenery overview location on the trail [27]. In this case it should be considered a node from the user's closest position, and thus require feature considerations accordingly (for instance providing an overview of parts of the VE, or function as a depth cue) [4].

III. METHOD

The study on how the (improved) exercise augmentation would influence intrinsic motivation was performed on two individual nursing home locations in the Copenhagen area of Denmark. Both locations had identical setups; a manuped was placed as part of the physical therapy area, as when used for its conventional use.

A. Installation

The technology necessary for the augmentation can be seen in Fig. 2. A desktop PC (Intel Core i5, 8GB DDR3 RAM, ASUS GTX760 graphics card) was connected to an Arduino UNO microcontroller, a 46' Samsung 1080p TV (model: UE46F6515) and a Logitech (model: Z623 Black) 2.1 stereo speaker set. The Arduino UNO was wired to a pair of Hall Effect magnet sensors placed on the manuped chassis. Magnets placed on the pedal arm of the manuped delivered signal when passing the sensor position on the chassis. The desktop PC was running a Unity3d (version 4.6 Pro) build, giving the user a choice between four VEs, as seen in Fig. 3. The design of the VEs followed the guidelines from Bruun-Pedersen, Serafin and Kofoed [4]. The choice of environment types was based on both feedback from the pilot study and availability of 3d assets in the Unity3d software.

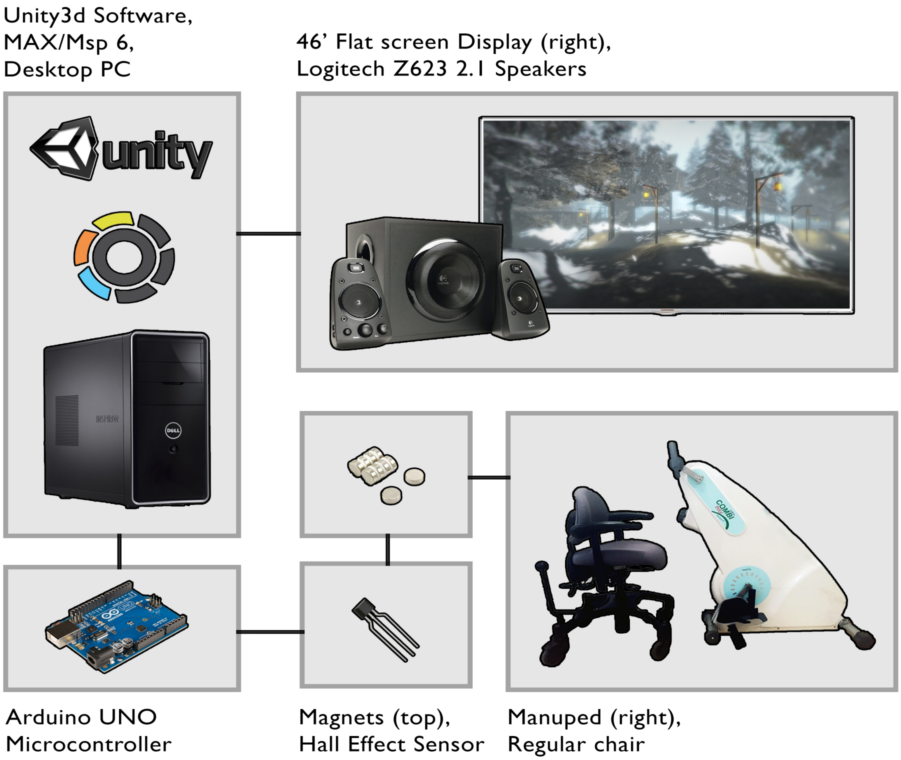


Figure 2 - The augmentation setup. Desktop PC receives the manuped pedaling speed from pedal arm-placed magnets, through the Arduino UNO and magnet sensors. The data is processed in MAX/Msp and sent to Unity3d, which moves the camera forward in the VE.

Unity3d 4.6 Pro is a capable graphics engine for the requirements to detail, with 3d assets from asset/pack developer K4 Manufactura[8] to add high levels of detail and realism to the VEs. The VE from the pilot study was reused, but revised from ground up according to the guidelines in [4], also replacing old 3d assets with content from K4 Manufactura. The four VEs were designed to be distinct from each other, and intended to offer a unique recreational experience between them. In a future work, we will go deeper into the concrete designs and design process of the four VEs.

Figure 3 - The Select Menu with the 4 recreational VEs: Vinterskov (Winter Forest), SøPark (Lake Park), Frilandet (Country Side) and Bjergtop (Mountain Top).

B. Participants

24 prospect subjects were asked to participate in the study and 17 residents agreed to participate. The subject group was chosen from the simple common denominators of being able to communicate verbally, be able to see and hear, and able to physically use the manuped. Of the 17, 8 completed all parts of the period, and 4 additional subjects were included during the process.

A consistent aspect of nursing homes is that the health of many residents is unstable. Of the 17 subjects originally participated with Q1, 9 were unable to complete the 4-month period. Reasons for not completing the agreed participation were mostly related to illness to the degree of being hospitalized, amputated, or otherwise sick to the point of not being able to exercise. Shortly after the study ended, one of the subjects died. So despite how some subjects participated practically the whole period (with e.g. two weeks before finishing), these were

[8] https://www.assetstore.unity3d.com/en/#!/publisher/585

suddenly in no condition to take the final Q2 and Q3 questioning sessions. Only 8 subjects completed all questionnaire rounds. In addition to these, 4 subjects who had not participated in the first questionnaires, completed very close to the 4-month period using the augmentation. Some due to being new, some simply starting an exercise and keeping an exercise routine with the VE augmentation. These 4 subjects (along with other potential subjects) were followed throughout the 4-month period, and asked to partake as respondents to the final round of the Q2 and Q3 questionnaires. This was both due to their consistent and almost equal participation to the 8 remaining subjects, and because so many original subjects were forced to drop from the program. We will onwards refer to these three groups as G1 (Q1, Q2, Q3), G2 (Q2, Q3) and G3 (only Q1). How much subjects were individually using the manuped prior to the study varied, from close to every day usage, to none at all. However, all subjects were able to relate to the conventional exercise form.

C. Measuring Intrinsic motivation

A questionnaire of 20 items was created, with 17 items based on Intrinsic Motivation Inventory (IMI)[9] factors. The factors chosen were Interest/Enjoyment, Pressure/Tension, Perceived Choice, Value/Usefulness, and Perceived Competence (3 items). All items used from IMI, were translated to Danish and altered slightly, replacing item formulations from “this activity” to “using the bike” or “using the bike while riding through one of the landscapes”. Due to the choice of discourse in the physical therapy, the word “bike” was used instead of “manuped” for the items.

The Interest/Enjoyment was given the highest quantity of items (5 items; for instance “I would describe using the bike as very interesting”), being the most central self-report measure for intrinsic motivation. Perceived Choice (3 items; for instance “I used the bike because I wanted to”) was considered important to see the difference in subjects’ level of autonomy. Perceived Competence (3 items; for instance “I am satisfied with my performance when using the manuped”) was chosen, as it is a positive predictor of intrinsic motivation due to its relation to the fundamental need for competence. Pressure/Tension (3 items; for instance “I felt pressured to bike, while doing it”) was included as a negative predictor, to see if such sensation was undermining the motivation to exercise while performing the task. Value/usefulness (3 items), which relates to how individuals regulate their experiences, was found interesting in order to see any indications to whether the VE augmentation created a shift in the inherently perceived value of the overall exercise experience.

[9] www. http://www.selfdeterminationtheory.org/intrinsic-motivation- inventory/

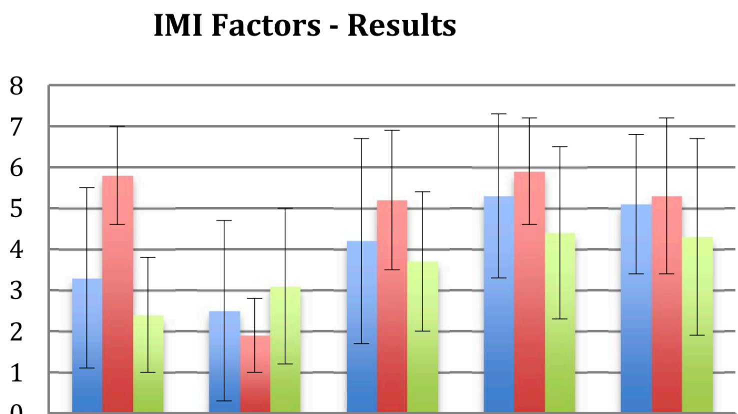
D. Procedure

Each subject was asked to participate by filling out the 20- item questionnaire before the test period with the VE augmentation began. The 3 items not IMI based, were open- ended qualitative items concerning any a) positive or b) negative aspects to the manuped exercise, and c) what could be a possible improvement to the experience. The main purpose of these items was to open for a contextual explanation of the quantitative results from the IMI items. The following 17 items in the questionnaire were IMI items, in a mixed order. Upon completing the first questionnaire with all subjects, the VE augmentation system was installed and used as a regular part of the physical therapy, for a period of a little more than 4 months After the 4 month period the participants were asked to fill out two versions of the questionnaire again: one version related to how motivating they had found their experience of using the augmented exercise bike, and one version related to how they in retrospect found the experience of exercising using the original exercise bike. Both subsequent sessions contained the same questionnaire items as 4 months prior, but asked into two different scenarios; namely 1) the experience of exercising with the VE augmentation, and 2) how they would expect the experience to be, if returning to the conventional exercise form without the VE augmentation. The reasons for reposing the items for the conventional exercise came from 1) a hypothesis among the authors, that some residents seemed uneasy to appear ungrateful about their conditions at the nursing home (e.g. in relation to the physical therapy section), and 2) that the augmented exercise might have placed a different frame of reference on how to regard the non-augmented exercise (positively or negatively).

We will onwards refer to the questionnaires as respectively Q1 (conventional exercise before VE augmentation), Q2 (augmented exercise with the VEs) and Q3 (returning to conventional exercise post augmentation). An important disposition to mention concerning the questionnaire procedure is the response method from residents. Only a few were able to fill out the forms themselves, and almost all subjects needed assistance from the test manager to read items aloud, as (first and foremost) vision with small letters and their ability to hold and place a cross with a pen was limited with many subjects. For others, a limited cognitive ability to comprehend the principle of the 7-point scale by the IMI procedure required assistance to give reply. This meant that the test manager would have to conceptualize a possible answer, such as “would you say that you agree or disagree”, leading to e.g. “so would you say that you completely agree, or only somewhat agree?”. This could even be followed up by “so, would you say that you lean towards better or worse than (answer)?” In practice, this meant that the 17 IMI items would often become a structured interview guide for the test manager to conduct conversation, which would lead to the filling of the 7 scale items.

IV. RESULTS

The fact that the 21 subjects should be considered three different subject groups means that relying on statistical analysis of the quantitative results is not meaningful. As such, in the following, we will indeed look at the quantitative results as an indicator of overall tendencies in addition to the qualitative responses, but it is impossible to be conclusive with any statistical approach, or perform statistical significance calculations. Comparing responses between groups to the same item, we observe the same, clear trends to the individual factors. When averaging results between groups on the same items, only 12 of 51 items have an average difference between groups of more than 1.0 and only one is as high as 2.1). As this data has had to be given a suggestive role, and seeing that numbers between groups share the same trends, we have chosen to continue by looking at the averages including all subjects who are respondents to an individual item, as the basis from which we will present and later discuss the results. The averaged results from each of the five IMI factors can be seen in Fig. 4. It shows results from respectively Q1 (blue: "Before VE"), Q2 (red: "VE") and Q3 (yellow: Post VE, no VE). Comparing results from all three questionnaires, the trend is that Q2 generally indicates the highest intrinsic motivation, with Q1 being second and Q3 indicating the least degree.



	Interest/Enjoy ment	Pressure/Tensi on	Perceived Choice	Value/Usefuln ess	Perceived Competence
Before VE	3.3	2.5	4.2	5.3	5.1
VE	5.8	1.9	5.2	5.9	5.3
Post VE, no VE	2.4	3.1	3.7	4.4	4.3

Fig. 4. The averaged results from the IMI items covering five factors to predict intrinsic motivation, respecitvely concerning (blue) manuped exercise without the VE augmentation, (red) manuped with VE augmentation after 4 months, and (green) the motivation felt when asked to go back to the conventional non-VE augmented manuped exercise.

From the five factors from the IMI, the most critical for intrinsic motivation is Interest/Enjoyment, which is also the factor showing the largest difference of averaged values between the three questionnaires. Results from the other factors have the same tendency, but show much less difference between averaged results compared to Interest/Enjoyment. Pressure/Tension, which as a negative predictor of intrinsic motivation shows a clearly lower average score compared to the rest of the averaged results, which indicates a relatively low negative effect on intrinsic motivation. Common for the last four factors are also that they indicate a relatively high prediction of intrinsic motivation. We will discuss this more in the coming section.

Across Q1, Q2 and Q3, responses on the three open-ended items are displayed in tables 1, 2 and 3.

Table 1 – Qualitative Items, Q1: Before Augmentation

Q1 responses about using the manuped (G1, G3)		
Positive aspects to this type of biking exercise?	***Negative aspects to this type of biking exercise?***	***Possible Improvements (what could make you want to bike more)?***
• Getting the legs working • The effect of the exercise (x3) • Doing an effort to stay functional • The sensation afterwards (x3) • Exercise, movement • To get off the bike • To be able to do other things • Lovely people • None (x4) • Physical improvement	• Boring • Not entertaining • Want to do other activities more than this • Repetitive • You have to pull yourself there • Don't remember any • None (x6) • Boring. You are caught once you enter that place • Demanding • Not interesting • It hurts	• To bike to Brighton • No, it does what you could expect it to • The timer-display could be bigger • Diversion • Entertainment • Can't think of any (x9) • Routine shift • A real bike ride outside, alone by yourself, peace, smell of summer

Table 2 – Qualitative Items, Q2: After VE Augmentation

Q2 responses about using the manuped (G1, G2)		
Positive aspects to this type of biking exercise?	***Negative aspects to this type of biking exercise?***	***Possible Improvements (what could make you want to bike more)?***
• I'm accompanied by images. It is lovely and diverse. Beautiful. • Not boring and a lot to watch. You are able to see new things. • Amazing. You see and experience something while you bike. You use more senses than if simply looking into a wall. • I like mountains • The mountain is amazing. There is something new	• No (x8) • It moves too fast. I would like to be able to have time to look at things. • That you are able to fall	• Perhaps more focus on results? • Perhaps try to make it become even more alive, so you seriously believe that

Q2 responses about using the manuped (G1, G2)		
Positive aspects to this type of biking exercise?	***Negative aspects to this type of biking exercise?***	***Possible Improvements (what could make you want to bike more)?***
all the time, and I always end up going 1 or 2 kilometers more. It is lovely to watch. • You speed up. Especially going up and downhill. You have to struggle up hill, but want to keep up downhill. You follow the trip as it is. Lovely tours. There is more to ride for. • All the landscapes are good. Time goes faster. It's pretty, all of it. I like the change of seasons (between environments). I switch environments a lot. • Good! You see something. Much better than the wall, or instead of looking into thin air. You keep going for longer, as you want to see what is around the next corner. • Time goes fast, while its all flowing by. It's like being in nature. • Snow and mountains are really good. It makes me think about ski vaccation. Something I would like to be able to try. And I like to search for the squirrel. • LakePark is fine. I like the Waterfalls. • There is a lot to look at. Turning around corners and seeing beautiful things creates expectations in me. There is always something new. I really like the weeds!	down in the mountains • It doesn't really make a difference to me. • I don't like biking. It does nothing for me, no matter whether there is a landscape or not.	you are riding in the mountains. And also more turns and the sensation of narrowness (in the mountains), where you have to stay right up against the cliff. • To not fall down from the mountain. • More speed and the ability to ride faster! • Nothing (x7) • To go slower.

Table 3 – Qualitative Items, Q3: Post VE, No VE

Q3 responses about using the manuped (G1, G2)		
Positive aspects to this type of biking exercise?	***Negative aspects to this type of biking exercise?***	***Possible Improvements (what could make you want to bike more)?***
• An activity that provides exercise (x4) • You get to move the body (x2) • Not really anything • I don't like to bike • It would be the same to me. I like biking and would bike either way. • You still get an (physical) outcome, even though I would probably not ride for as long (as with the VE). • It would still be exercise, which is	• Well, it would be horrible to sit there now, and simply look into the wall. Awfully boring. • It would be quite boring to sit there. You would have to drag yourself there, haha. • Well, I wouldn't want to go back to that. • It's the same to me. I would bike either way. • I don't like to bike. • It would be too bad to have to miss these lovely experiences. I think I would bike less far. • It would be tiresome. • If there wasn't landscapes, I would find something else to think about. My approach to biking is the same, landscapes or not. • I don't feel like looking into the wall	• By keeping the landscapes (x7) • Nothing I didn't mention before (Q2). • If not the landscapes, then something that would take your mind off the biking. • Don't know, besides the landscapes. • It would be fine either way. I like the bike, and don't mind sitting

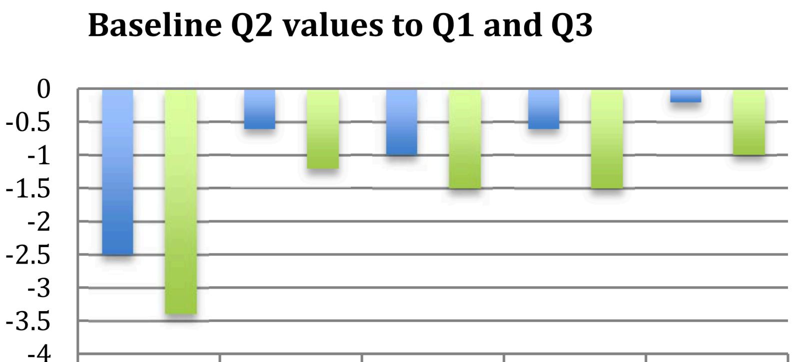
Q3 responses about using the manuped (G1, G2)		
Positive aspects to this type of biking exercise?	***Negative aspects to this type of biking exercise?***	***Possible Improvements (what could make you want to bike more)?***
good for you. • Well, I guess it has to be done, and its good for the body	again. Nothing interesting about that. Then, biking will become a chore again. • It will feel like it would take longer to bike the same distance. • I have gotten used to looking at things. I would miss that.	there in my own toughts.

V. DISCUSSION

Before discussing the quantitative results and qualitative responses, we will shortly address the construct validity of the study. As described earlier, many subject had to drop from the study, due to health issues. This is unfortunate for the validity of the results, and destructively affects the possibility of meaningful statistical analysis.

But loosing participants to health issues without warning is an everyday condition when performing longitudinal studies at a nursing home. One of the residents who dropped from the collaboration (who unfortunately died shortly after the conclusion of the study) was by far the most physically active of all residents at the nursing home, using the manuped 4-6 hours weekly. The point is that while loosing construct validity, the findings remain relevant and pave way for further studies, despite becoming more suggestive than conclusive.

IMI items. As previously mentioned, we cannot subject the analysis and discussion of the IMI items to statistical analysis, due to the unusual subject distribution between groups. Meanwhile, we do see a general trend in the results from the IMI items, namely that Q2 responses with no exception indicate a higher level of intrinsic motivation than both Q1 and Q3, with Q1 suggesting a higher level than Q3. The factor where values most clearly distinguish themselves between questionnaires is Interest/Enjoyment (as is highlighted in Fig. 5). As the main measure for intrinsic motivation, Interest/Enjoyment is the most interesting factor. A score of 5.8 on average (Fig. 4) is an encouraging result, which indicates that the augmentation is delivering a generally intrinsically motivating exercise experience.



	Interest/Enjoyment	Pressure/Tension	Perceived Choice	Value/Usefulness	Perceived Competence
Before VE	-2.5	-0.6	-1	-0.6	-0.2
VE	0	0	0	0	0
Post VE, no VE	-3.4	-1.2	-1.5	-1.5	-1

Figure 4 – Overview of the value difference between IMI factors for base-value Q2, and the results from Q1 (blue) and Q3 (green)

But the highest significance lies in the difference of this factor when comparing Q2 to Q1 and Q3 results, as there is a tangible improvement to the overall intrinsic motivation for the Interest/Enjoyment factor for the exercise. Where the other factors do not change radically, Interest/Enjoyment has the lowest indication of intrinsic motivation by far in Q1 and Q3 (Pressure/Tension being a reversed scale). We will discuss Interest/Enjoyment more in relation to the qualitative items.

The remaining four IMI factors generally have higher values for Q1 and Q3 than Interest/Enjoyment, ranging from about neutral (4) to a positive (5+) for most Q1 as can be seen in Fig. 4 (including Pressure Tension if considering its reverse nature). The general trend outside Interest/Enjoyment, is a minor (positive) difference between Q1 to Q2, and a comparatively larger (negative) difference from Q2 to Q3.

Such results signify that while the augmentation seems to be improving upon the IMI factors generally, many of the nursing home conditions for the exercise experience should considered very acceptable, with or without the augmentation. Especially Q1 responses (before introducing the augmentation) are quite positive for factors other than Interest/Enjoyment.

The reason for this can be found in the qualitative responses and observations while performing the study. The low Pressure/Tension values reflect the competent, empathetic and inclusive approach towards the residents, by the physical therapist staff. The staff kindly but surely pushes residents to increase performance, but with a very tuned eye for personal limits. Residents seem to realize the necessity of such pushes, but never appear fundamentally pressured against their will. This factor therefore seems to have never prohibited intrinsic motivation. Meanwhile, the 1.2 point jump from Q2 (1.9) to Q3 (3.2) does indicate that residents feel more autonomous with the thought of using the augmentation.

Perceived Choice shows an increase from neutral (4.2) to positive for Q2 (5.2), while turning slightly negative for Q3 (3.7). As can be seen from the qualitative responses in TABLE 1, many residents originally choose to exercise because their physical health demands it. While this possibly remains true as well with the augmentation, results indicate that it indeed does affect the perception of choice somewhat towards positively choosing to exercise, more than doing because it's considered a necessity.

Value/Usefulness shows fairly high values across Q1 (5.3) and Q2 (5.9). As mentioned in the Background section, as well as suggested by the qualitative results in TABLE I, most residents are not in doubt about the physical benefits of the exercise. So that this factor has high Q1 and Q2 values is no surprise. That Q3 has 4.4 probably does not mean that this has changed, but perhaps that the frame of reference has changed for the subjects after being exposed to the augmentation.

The Perceived Competence is positive for Q1, Q2, but neutral for Q3, decreasing 1 point from Q2 to Q3. This indicates what some subjects responded in the qualitative items, that they believe performance will decrease without the augmentation, which follows the qualitative responses to Q2, showing how some subjects feel that their performance is positively affected by the augmentation.

Qualitative items. Some of the reasons behind the change in Interest/Enjoyment factor seem to be present here. In Q1, the positive responses to the exercise focus on its merits as an activity to boost physical health (e.g. "the effect of the exercise"). Much of the satisfactory sensation of the activity seems to lie in the post-exercise sensation, along with the long- term physical perspective of performing it, which confirms that it does not lie with the activity itself. On the negative side, the activity is largely considered uninteresting, boring and repetitive. In this sense, subjects' Interest in the activity seems to be the physical maintenance, whereas their Enjoyment does not seem related to the activity, but more to being done with it. 4 subjects did not find any positive aspects to the exercise. When asked about possible improvements, subjects responded to want entertainment, diversion, routine shifts, or a real bike ride. However, many subjects also state that it does what you expect it to, or that they do not have any suggestions to improving the exercise. This might suggest an important point within the Q1 results; residents often try to seem contended with what they have, and are not often very imaginative about alternatives. This is also indicated by how 6 subjects did not find any negative aspects to the exercise for Q2.

For Q2, many responses contrast those of Q1. Positive responses concern themselves with interest in the augmentation and the experience of its content. Subjects respond that beauty and diversity are important features to both the VEs and to the exercise experience. This seems to promote a desire to explore the VE, and expectations of surprise around the corner, which increases interest to keep pedaling, and enjoyment in what continuing the exercise brings to their experience. Perhaps through this, some subjects report that the augmentation is able to reduce the perception of exertion and the decrease the perceived length of time spent exercising. The augmentation seems able to create associations, and to some, a convincing

experience of riding through nature. And while no environments are negatively mentioned, the mountain environment receives most positive mentions, also in this regard. Negative responses are less prevalent in Q2 compared to Q1, and are comprised of generally not caring or liking to bike, the one implementation mistake in the mountain VE (falling down from the mountain at a specific point/direction) and one subject who did not know that she was actually able to stop inside the VE and observe the surroundings. Improvement suggestions are a more result-oriented exercise, to go even more into the experience of being on the mountainside. The latter speaks to the potential of the augmentation more than anything else.

The Q3 feedback somewhat resembles Q1, in relation to how the positive aspects of the exercise are once more focused the rational merits of the physical activity. However, negative feedback relates a lot to the lack of an augmentation, and how it would once more increase boredom, become a chore, and that it might lower the effort and the desire to exercise. Improvements (besides dominant responses to keep the VEs), would be something else to distract from the exercise. The last comment also shows the difference to Q1, in how subjects now have a different reference to how the manuped exercise could feel, and what they would like the activity to include in order to make it more interesting or enjoyable.

VI. CONCLUSION AND FUTURE WORK

This paper seeks to illustrate the situation of elderly nursing home residents in terms of their (lack of) motivation to exercise on a conventional exercise device, despite knowledge of its merits and ability to perform the activity. We use the theory of intrinsic motivation from the Self-Determination Theory (SDT) framework, to measure any changes in multiple factors of intrinsic motivation for residents using a VE augmentation of a regular manuped exercise activity, using items from the Intrinsic Motivation Inventory (IMI). Results suggest that the augmentation increases the level of motivation for all motivation factors in the study, but predominantly in the Interest/Enjoyment factor. In the discussion, we argue that the lack of dramatic differences in the latter factors might be due to how many of these factors represent aspects of the physical therapy clinic/procedure (at the nursing home), which works very well. However, the actual experience of performing the exercise activity seems to change noticeably between using the augmented exercise and the conventional. Qualitative responses outside the IMI items in the test looks to almost fully support this.

The central nature of intrinsic motivation revolves around performing an action, because it is inherently interesting or enjoyable. In our study, the Interest/Enjoyment factor showed to be an essential barometer for determining intrinsic motivation when using virtual environments (VEs) to augment exercise. The positive aspects that formed this experience were reportedly (natural) beauty, interesting VE content, and environment exploration while exercising, which for some subjects afforded a reduction in perceived exertion and desire to exercise for longer.

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CHAPTER 11. PAPER IV. NURSING HOME VS. RESEARCHER: ESTABLISHING THEIR NEEDS WHILE FINDING YOUR WAY

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Abstract - Residents at nursing homes need to exercise to retain self-efficacy. But all the while, many do not seem to want to prioritize exercise routines over leisure activities. The first part of this chapter analyzes the potential reasons for this lack of exercise commitment at a nursing home in Copenhagen, Denmark, and show a solution to overcome such obstacles, by augmenting the exercise routine with the accompaniment of recreational virtual environments. The second part of the chapter shares insights from the experiences from spending 3 years with the unique challenges and complex conditions that researchers face, when operating and navigating the specific field of nursing homes, due to the inherent characteristics of its context and users.

Keywords: Older adults, Rehabilitation, Exercise, Nursing Home, Virtual Environments, Intrinsic Motivation, Trust

1 Introduction

This chapter bases itself on a couple of studies performed in relation to a PhD project, which has been running over the course of three years. The project has investigated the background behind the problem of inactivity with regards to nursing home residents routinely exercise at a Danish nursing home, Akaciegården, in the Copenhagen area. From the research, it has been possible to map various aspects to nursing home life, which seem to oppose a desire to maintain a regular exercise routine for many residents. It has also been possible to implement and test a solution, which has positively affected some of these aspects, by using virtual environments to augment the exercise into a different type of experience. Last but not least, it has been possible to experience the (possibly) deceptive complexity of working as a contemporary media technologist researcher, within the very specific context of older adult nursing home residents as the users.

Primarily concentrated around the context of two individual studies performed for the project, this chapter provides an elaborated insight into the process of problem identification, solution design and results throughout the two studies, and afterwards discusses the implications of performing such research.

The initial incentive for engaging this specific area of research was a desire to combine an exercise routine for elderly users with an augmentation design using virtual audiovisual technology. The applications of virtual reality technology have been investigated for some years now, but as this project has come to realize, the field seems to yet lack the maturity of covering requirements and best practice frameworks for user demographics such as older adults. From a societal perspective, the elderly demographic will be growing rapidly over the next decades [1], and there is a need for methods to help maximize the longitude degree of independence for older adults. Exercise is one such method, but while research with the elderly segment and commercial entertainment technology has been given some attention for a period, such as with the Nintendo's Wii console or Konami's Dance Dance Revolution game [2] [3] [4], the body of research on tailored technology and content, designed specifically for exercise purposes for nursing home residents is both sparse and necessary [5]. It is imperative that the sense of meaningful purpose of a newly applied technology such age group demographic is considered [6], and what motivates physical activity behavior between age groups is very different [7].

Throughout its duration, the project has been fortunate to gain close access to the daily-living nursing home residents and their routines, which has facilitated iterations of observation sessions, interviews, private visits and social interactions with residents and staff. The resulting outcome has a variety of insights into what constitutes the nursing home life, as well as an understanding of residents' ability, approach, opinions and practices related to daily physical exercise. This has enabled the project to positively touch upon the somewhat untouched potential of virtual technology and media, specifically for nursing home exercise activities. And it has given an important understanding of what constitutes constructive procedures and necessary precautions to consider, when working scientifically with this type of technological development, with this type of user group.

The first part of the chapter (sections 1 to 4) takes a closer look at the aspects that form the exercise reluctance problem in the context of the nursing home. Thereby the reasoning behind the solution design is also detailed, leading to a description of both the solution design itself and the results from two studies using the solution; one study which initially validates the solution design [8], and another study which evaluates the motivational implications on its implementation at the nursing home over an extended period of time [9]. The second part of the chapter (section 5) addresses a seemingly overlooked aspect to such research, which is the inherent challenges of working as a researcher in the context of a nursing home, with nursing home residents as the target user group. While these considerations are not explicitly detailed in the first part of the chapter, they have been a necessary part of the research approach throughout the project. The second part of the chapter thereby contributes insights to research practices, which is believed by this author to essential for any future endeavor within this field of research.

2 Physical therapy and the manuped

When moving from their original home to a nursing home, many facets of everyday life is made easier for new-coming residents compared to their previous living. This is partly due to the now closely available assistance from personnel, the optimized demographics of the nursing home increases independence, relating to daily activities such as toilet visits or overall indoor mobility, which increases overall life quality [10].

Rehabilitation is another area where nursing homes often have much to offer residents, in terms of attendance flexibility, availability and variance of activities. In Denmark, many nursing homes encourage physical therapy as part of the everyday activities at the home. The level of independent living and health status is an important factor of the quality of life for any person, and especially for these elderly segments [11]. Physical activity on a regular basis is found to improve sarcopenia, physical function, cognitive performance and mood in elderly adults [12], in addition to being able to maintain independence and retain self-efficacy [13]. Exercise makes a difference in everyday life for residents, as it fundamentally enables other activities. Examples of everyday situations where lacking self-efficacy can influence quality of life, are getting dressed, walking, or even controlling one's own drinking glass and eating utensils.

At Akaciegården, exercise and physical independence is a central part of the nursing home philosophy, but personnel are facing difficulties inspiring a portion of residents to maintain regular exercise routines [8]. Factors such as *independence* and *self-efficacy* could be regarded as rational, reasonable, and qualify as motivational reasons why exercise should be an attractive activity. Meanwhile, studies suggest that it does not reflect the engagement of many nursing home residents [8] [9].

Many residents who do not exercise regularly do not seem overly concerned with their lack of commitment, despite being well aware on the positive effects it could bring to various physical deficiencies. When asked into the reason for not exercising, many residents choose to deprioritize exercise because a) they don't like it for one or several reasons, b) they had been exercising regularly at one point, but couldn't find the motivation to return, c) they feel that exercising too often interferes with other types of leisure-based activities overlapping physical therapy sessions, or d) they are simply too lazy [9].

The physical therapy center at the Akaciegården nursing home is open in two separate 2,5 hour sessions a day, four times a week, with two physical therapists present in each session. Average resident participation is 10-15 during morning session, and 6-12 in the afternoon depending on the weekday due to weekly social activities on certain days. Therapists are very attentive and social towards the present residents in general, but certain exercises (any walking or standing related exercises) need the complete and attentive presence of either one or both therapists. Physical therapy sessions are therefore a race on resources, in terms of therapists' capability of placing appropriate personal attention to all residents who need it. It also means that exercise activities that residents can perform unassistedly have high value for the daily exercise routine. The most essential exercise activity for unassisted is a machine called a manuped; a chair-based bike device for arms and legs (see Fig. 1). In the context of the nursing home, the manuped is an all-round exercise device.

Figure 1 - The Manuped exercise device

A manuped activates most parts of the body to varying degrees, and affords exercise with a high variance of intensity. Residents can use it unassistedly, as it requires no active balancing, or strength comparable to standing up independently. Nor does it demand sudden reactions or swift coordination changes (anything demanding dynamic muscle activity or quick coordination and balance). This combination of traits makes it safe for the physical therapist to leave a resident alone while using the device. Devices such as the manuped become essential, due to the resource limitations for the two therapists, as they can have more residents exercising at the same time, without having to actively attend all of them.

The manuped exercise is a single-person activity. Practicing residents are facing a wall while exercising, mainly because of the logistics placing them by the device, from e.g. their wheelchair. It does, however mean that once they are in place and start using it, residents are practically left alone for the duration of the exercise (10 minutes for the weakest, and approx. one hour for the few strongest). From both early interviews and casual conversations with residents, they generally really like the physical therapists. Much of what was appreciated about the physical therapy center had to do with the two therapists. Another very clear opinion among residents was that although using the manuped is good for the body, such activities are extremely boring, and difficult to want to do.

2.1 Why residents dislike exercise

Many residents struggle with obstacles such as balance issues, pronounced lack of muscle strength (a combination of lack of exercise and sarcopenia), coordination difficulties, arthritis, or other chronic conditions [14]. Besides these, regular illness generally hit harder and last longer at this age. The effects of this were partly the reason why many residents expressed reluctance to make the effort to go exercise. When thinking about the physical therapy, they were thinking in parallel about the pain and discomfort affiliated with the activities. Of course, the impact of this varied between individuals, partly due to differences in physical performance/limitation, partly due to personal distaste for the associated pain, and partly due to their individual desire to overcome it. The last point is important, as almost all residents experience pain or physical issues to some degree, while exercising. So while the perspective of pain during exercise is a fact for most, it depends on the individual if it holds them back, is not important, or perhaps serves as a reminder to go exercise, as the sensation will only worsen if they do not. All scenarios were met during conversations with residents during visits.

2.2 Returning from illness

Periods of illness are a big part of everyday life at a nursing home, which is why periodical absence from an exercise routine does not equal a lack of motivation. However, the two are potentially linked, as, physical conditioning from exercising decays much faster than at younger ages, during periods of illness. When the illness has worn off, residents are often left with the sensation of having to start all over again. For some nursing home residents, this can mean reestablishing the ability to walk. If a resident has not been able to maintain a regular exercise routine, physical therapy activities can be very physically demanding. Exercises are painful, and the residents cannot help but observe, compare and acknowledge their own inadequacies, when they for example with a physical therapist under each arm to aid the ascent, as they try to simply practice standing up from a chair. In addition, performing (relatively speaking) intensive exercise, affects their body substantially the rest of the day, perhaps even more. Especially if they have not been maintaining a regular routine, many residents are fatigued after a physical therapy session, to the extent that it sometimes means that they cannot engage in much else for the remainder of the day. Residents therefore go into a cycle of training, where they hit a barrier, and then struggle for an extended period of time to get back into a shape where they are actually able to perform simple tasks (such as standing up).Exercising for the pure sake of long-term physical improvements can thus be regarded a substantial, and unstable investment. Observing a resident return to exercising after a longer break, give several impressions. One is clear happiness about being able to return to exercising and to the nice environment of the physical therapy center. Another is sadness and irritation concerning the lost long-time effort from before the break. It is a cycle that repeats itself for many residents, which has been evident from many conversations along the project. And it has shown to be a factor that makes it difficult for residents to prioritize physical therapy. Some residents do return to their exercise routine after longer periods of illness, however. This has especially been pronounced for residents who from previous occasions have gained personal experience with the physical difference between returning to exercise and staying away from exercise.

2.3 The alternative

Most residents at Akaciegården are physically or mentally unable to leave the nursing home at their own initiative. If they do, they require personnel (or family) assistance, which is often not possible within the in-house resources, on any general scale. This means that social and/or entertaining leisure activities are hugely important for the residents, as most residents are almost completely limited to the experiences that are offered inside the walls of the nursing home. The nursing home arranges a large number of such in-house activities per week, where residents gather with a group of personnel, who deliver or conduct the event. Events are typically quite casual, for example rhythmic and singing gatherings, a movie, coffee and cake in the yard, card or board games, etc. As it is an important priority for the events that any resident should be able to participate, the events have a minimum of physical activity required (such as crossing squares on a paper, eating biscuits or drinking coffee while sitting on a chair or wheelchair). The leisure activities at Akaciegården are enjoyed by residents, and for many reasons. They increase personal bonds between and within personnel and residents, fill the residents' days with enjoyable content and experiences, and activate (or reactivate) residents socially. Meanwhile, with a fixed perspective on increasing the desire to exercise, leisure events can be seen as a diversion, which leads residents away from regular exercise routines. And while these authors would never encourage less leisure activities at Akaciegården, they do represent a challenge for the physical therapy personnel, in terms of keeping residents with their programs.

2.4 Laziness?

As mentioned earlier, a fair amount of residents who did not exercise a lot, claimed to be simply too lazy to exercise regularly. When asked into the reason behind their laziness, many residents described that it came from a combination of the areas just described; from pain, physical difficulty and boredom of sitting alone facing a wall while exercising, to the lack of any leisure entertainment during exercise sessions, the knowledge of the potentially lost effort if hitting a barrier, to the calm, relaxing and entertaining activities offered other places at the nursing home. From this outset, it seems that while some residents find themselves to be too lazy to exercise, they have a background of understandable reasons to simply not feel very positive about the activity itself.

3 The conventional Manuped exercise experience

From observations of the daily routines in the physical therapy, the manuped exercise was by far the most shared and commonly used. It was the most resource relieving exercise form for the physical therapists, but evidentially also the most repetitive and socially isolating exercise experience in the room. Over the years visiting the nursing home, numerous conversations were had with residents, concerning the manuped experience. Two iterations of interview rounds were done as well with residents in relation to the studies, where residents were asked to describe their opinions on the conventional manuped exercise [8] [9]. Interview asked into the positive and negative aspects of the (conventional) exercise, as well as opinions about possible improvements [9].

Positive aspects predominantly related to the function and usefulness of the manuped, as a facilitator of physical conditioning. Positive responses were, for example *getting the legs working, doing an effort to stay functional, to be able to do things,* or *physical improvement.* Negative sentiments referred more to the actual experience of the exercise, in terms of how it was *trivial, uninteresting, boring, repetitive, demanding,* and *hurtful*, describing the opinion about the activity, as e.g. "*you have to pull yourself there"* or *"you are caught once you enter that place"* [9].

An interesting situation happened when subjects were asked about possible improvements to the experience. Most subjects could not imagine any possible alternative. This was eventually found this to be characteristic for the user group. Nursing home personnel explained that many do not want to seem ungrateful of the offerings placed at their disposal, and have a tendency to humbly accept things as they are at the nursing home without thinking about questioning it. Some responses did however encourage changes; by e.g. simply needing a *routine shift* or a *diversion*, while others again suggested the same, but coining it *entertainment.* A few had the imagination to associate to "*a real bike ride outside, alone, on your own, peace, and the smell of summer"* or *"to bike to Brighton"* (where she was originally from). The pattern is that positive responses about the manuped exercise were health oriented and rational, while negative responses related to the experience of the actual exercise activity, Potential improvement responses related to the experience by removing the boredom and repetitiveness from the exercise form.

3.1 VE augmentation: an extra layer

Based on the responses, it was decided to augment the exercise experience, to bring a new layer to the manuped, so the exercise activity would be accompanied by an audiovisual experience. A virtual environment (VE) was set up in connection to the manuped, to react to the residents' press on the manuped pedals. When they pressed the pedals, the VE moved forward and gave a sensation of a bike moving forward in space inside the VE. As such, a manuped exercise would (to a certain extent) reflect a bike ride through a (virtual) landscape.

This implementation was based on the following parameters. A fundamental part of the setup was to not change the form and function of the exercise. On the perspective in interaction design, and possible gameplay oriented elements, it was decided to the keep the interaction with the system based on the normal input scheme of the conventional exercise. This would make the augmentation simple and easy to transfer to the users. The background for this decision came from an intermediate focus group session performed with a Nintendo Wii (using Wii Sports), which attempted to establish and evaluate the residents interaction abilities and preferences, in terms of interaction possibilities to perform while exercising.

The focus group experience led to two conclusions:

a) The residents in the focus group were practically unable to interact with the simple Nintendo Wii gameplay, due to cognitive and motor-based deficiencies,

b) Aiming, from a developer's perspective, for a gradual improvement of interaction skills along a hypothetical timeline seemed dangerous. It was clear that the residents (all besides one) who were unable to perform the required actions within the Wii Sports game experienced a personal defeat and embarrassment, not a personal encouragement to learn a new skill. The rationale was that if even remotely more demanding interaction requirements were included, a substantial portion of the users might be alienated before they even started.

Even without changing the interaction significantly, it was expected that such augmentation could redeem some of the cardinal complaints of the conventional manuped experience. On a very basic level, the augmentation would change repetitive experience of looking into a blank wall during every single exercise, looking into a dynamic, constantly changing landscape view in motion. Instead of simply performing trivial pedaling, an augmentation would give the effort of pushing the pedals an immediate feedback reaction and possibly an immediately valuable payoff. Another possible result could be that the attention to pain and physical inability, could be changed to the augmented exercise which could provide a diversion of attention, distracting the resident's focus from the activity related pain, as also suggested by de Bruin, et al. [15].

An aspect to the VE augmentation that could have a strong impact is the ability to transform the indoor manuped bike ride to an "outdoor" bike ride. In addition, supposing that the link between actions and system response would feel natural, and that the VEs would be able to provide a convincing experience, residents might be given an option, which they might have thought to be lost - the ability to unassistedly travel to other places outside the nursing home. By that hypothesis, instead of being a lonely, uneventful and trivial single-person experience performed as rationally forced chore, the manuped exercise could suddenly be facilitating a unique, enjoyable and perhaps even personally valuable experience.

With the conventional manuped exercise, the only reward of the exercise actions is the long-term goal of better fitness, leading to gradually higher independence and self-efficacy. This long-term goal would now be supported by a short-term value from the daily ventures inside the virtual landscape. As such, a hypothesis about the augmentation was that the hard work might transform into something more resembling leisure time - something that was previously suggested to be of high contrast to the manuped exercise. All in all, the goal for the manuped exercise would be a place where residents would want to be, instead of a place "you cannot wait to get away from".

4 Solution design

As explained in more detail in [8], the first study of the concept was done through a small-scale, summer countryside VE, with 10 participants trying out a single exercise run. Results suggested definite promise, with user responses relating to the previously mentioned expectations for the augmentation. The system implementation can be seen in Fig. 2. To be able to track the user input actions, magnets and Hall Effect magnet sensors was attached to respectively the manuped pedal arm and manuped frame exterior, one for each side of the manuped to track each pedal push. The sensor was wired to an Arduino UNO microcontroller, which forwarded the sensor output to a desktop PC (Intel Core i5, 8GB DDR3 RAM, ASUS GTX760 graphics card). The PC then was running a Unity 4.6 based build of the VE, which was visually displayed (running an average of 45 fps in 1080p resolution) on a Samsung 46' LCD TV. In the first study, a pair of Sennheiser HD650 headphones provided the VE soundscape, but as headphones were generally found to be intrusive, the later study used a Logitech Z623 Black 2.1 stereo speaker set.

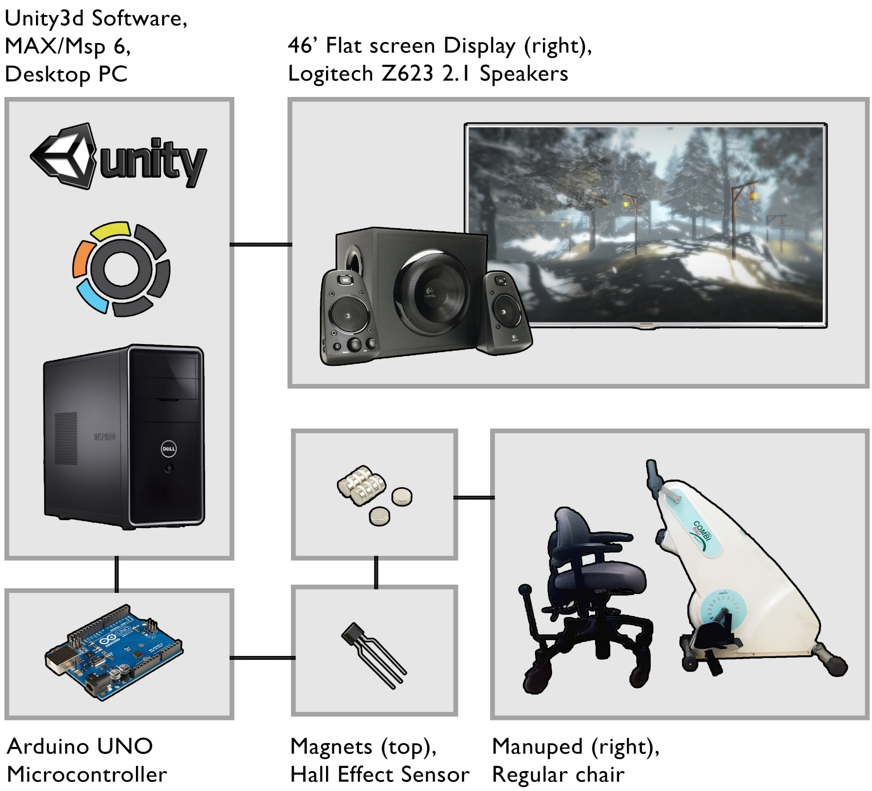


Figure 2 - The augmentation system

The dynamic, moving visuals (examples from the first study VE in Fig. 3) provided a welcome change of "scenery" from the original static view of the wall. Residents did in fact connect the manuped pedal actions with the forward movement through the VE, and the introduction of a (virtual) landscape to explore were very positively received by most subjects. They accepted the experience of traveling inside the (VE) landscape, and many expressed something close to a thrill, concerning being able to experience the natural beauty of the landscape.

Figure 3 - The virtual environment used in the pilot study

The feedback of the system was perceived to place the (short term) purpose to the exercise actions, and one subject even mentioned that she now felt the ability to move herself forward outside the nursing home, which was a feeling she had not experienced for a long time (due to her weight issues in a wheelchair). In this sense, the pilot gave a real sensation of the exercise being transformed into something that could qualify as an enjoyable experience, which in turn placed it much closer to being classified as a leisure activity. However, the earliness of the implementation, as well as the fact that this experience was a first test, did not elude some of the subjects, who expressed the need for a higher diversity in VE content and more VEs to choose from, if the augmentation was to retain leverage over linger periods of time [8].

For the next study [9], a larger collection of (four) more content- and size-wise complex VEs was designed and implemented, using a design framework developed for the exact purpose [16] (as can be seen fin Fig. 4). The purpose was to test the concept over a longer period of time and to evaluate the residents' intrinsic motivation to exercise, comparing the experience of the conventional manuped exercise with the augmented one. During the development of the new implementation, over the course of approximately a year, the nursing home residents were only subject to the conventional manuped exercise. Prior to installing the new system, a select group of subjects were responded to a set of questions relating to their positive, negative experiences with the exercise, their suggestions to improvements, and their level and orientation of intrinsic motivation (as defined by Ryan and Deci [17] in relation to Self-Determination Theory) in relation to the manuped exercise.

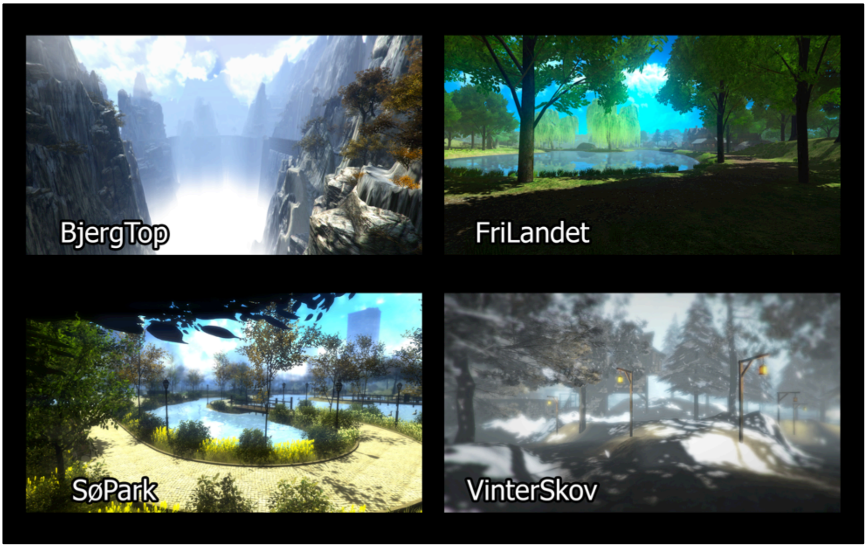
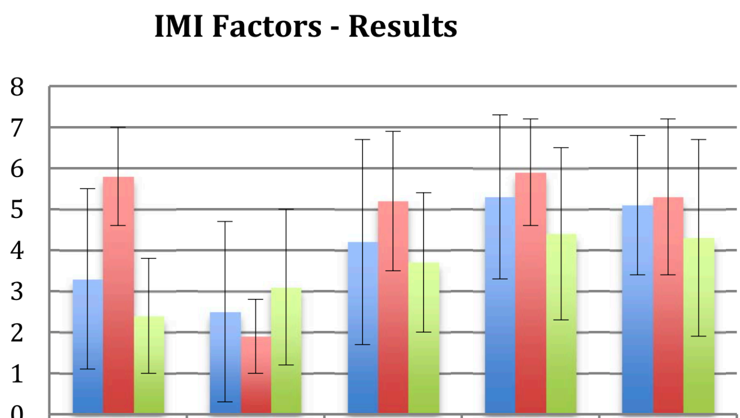


Figure 4 - The four virtual environments used in the longitudinal study (with Danish titles).

The level was measured on a 7 point scale, whereas the orientation was measured based on items relating to different factors of intrinsic motivation, taken from the Self-Determination Theory related Intrinsic Motivation Inventory[10] (IMI). The orientations (factors) chosen for the study were Interest/Enjoyment, Pressure/Tension, Perceived Choice, Value/Usefulness, and Perceived Competence [9]. Subsequently, the new augmentation was installed and ran at the nursing home for more than four months, after which the residents were asked to respond to the same questionnaire, only this time concerning their experience with the augmented exercise experience. In addition, they were also asked to respond accordingly to how they would feel about going back to exercising without the augmentation [9]. Results concerning the IMI orientations were very interesting, and can be seen in Fig. 5. Subjects responded as expected before the augmentation had been introduced ("Before VE"), if not slightly more positive than expected. As previously stated, it was the impression that they did not want to seem ungrateful, and that they were generally trying to be content with the opportunities they were offered. Results concerning the augmentation ("VE") were consistently more positive towards the augmentation, and most said it had become an integrate part of their reason to want to exercise on the manuped. And results from residents concerning returning to the conventional exercise ("Post VE, no VE") showed a clear negative curve, compared to both the augmentation and especially the original responses to the conventional manuped exercise. Four of the five motivation orientations had similar patterns between the three "conditions", with a not too high increase from the conventional

[10] www. http://www.selfdeterminationtheory.org/intrinsic-motivation- inventory/

towards the augmented exercise, and then a larger decrease in motivation in relation to returning to the conventional exercise. One motivation orientation, Interest/Enjoyment followed the same trend, but stood out by having much larger jumps between values.



	Interest/Enjoyment	Pressure/Tension	Perceived Choice	Value/Usefulness	Perceived Competence
Before VE	3.3	2.5	4.2	5.3	5.1
VE	5.8	1.9	5.2	5.9	5.3
Post VE, no VE	2.4	3.1	3.7	4.4	4.3

Figure 5 - The levels and factors of intrinsic motivation from the longitudinal study [9]

Manuped exercise responses, Intrinsic Motivation

The subject responses to the positive, negative and possible improvement aspects of conventional manuped exercise, all suggested that which was previously explained in this chapter; a useful activity for the functionality of the body but boring and repetitive. The augmented was praised highly in these categories, and the thought of returning to the conventional exercise form was poorly received. Meanwhile, by far the most clearly significant difference between "conditions" in Fig. 2 is that of Interest/Enjoyment, whereas the remaining orientations are much more similar. What the original publication suggested as the reason was how many aspects of the other orientations were already quite ok for the conventional exercise form [18]. The results suggested improvement by the augmentation over the conventional form, but none even remotely close to the difference of Interest/Enjoyment. Combined with the user responses on positive/negative/improvements, which very clearly suggested the augmentation experience to be a substantially superior exercise experience, it looks logical to suggest that the leisure and entertainment aspect of the activity itself has proven to be a strong factor in improving the desirability of such type activity for nursing home residents. From that perspective, the inclusion of the augmentation, as a transport to another place, as well as being an entertaining layer on top of a meaningful exercise, could be argued to make a lot of sense. Both studies showed also suggested how content variety, details and consistency was important for the users experience of riding through the VE, as well as liveliness inside the VE (animals, water, wind, etc.) [8] [9]. These aspects to the experience give believability to the experience, and add to the sensation of a recreational ride through nature, as also highlighted more in a paper by Bruun-Pedersen, Serafin and Kofoed, discussing various key considerations to design challenges when creating custom VEs for this purpose [18].

5 Research challenges: nursing home residents

Essential to the research just described was a constructive collaboration relationship with the nursing home residents. It demanded to meet them in their environment, during their everyday life routines at the physical therapy, and even required disturbing their privacy, unannounced, on occasion in their private homes. Nursing home residents have unique characteristics as a user group, and it is necessary to consider those contextual properties in the planning and execution of studies. Many of these characteristics were not considered when beginning the project. Neither was the importance and necessary degree of empathetic understanding of the individuality and context of the residents, all of which were gradually discovered to be cardinal parts of conducting the research with residents.

5.1 Planning of the study

On the practical level, it became necessary to recognize the daily rhythm, capabilities, and limitations of the residents as subjects. In this sense, planning is extremely important, but so is a high level of flexibility. Sudden changes cannot be expected from residents, but at the same time it is not possible for a researcher to rely upon agreements or schedules bring upheld by residents. This is not due to conscious neglect, but most often to the constant risk of illness, otherwise immediate loss of strength to participate or simply dementia. In this perspective, studying nursing home residents requires patience and studies require a lot more time than what would seem rational on paper. Numerous unforeseen occurrences can happen from one day to the next. In the first study, 15 residents signed up, 10 participated, and the study took twice the time to perform the single trial in the pilot VE than expected. In the 4-month study, 17 agreed to participate and 8 completed the study (new subjects were added to the pool along the study, however), due illness, dementia, amputations, death, or hospitalization. It has also occurred a few times that a subject suddenly declined participation with no explicit explanation or reason, but overall, this type of situation has been rare. Over the course of a longitudinal study, a pre-defined group of subjects is therefore bound to change, sometimes dramatically, and it is a part of this type of research to follow its course.

5.2 Keeping the residents reminded

Especially when performing longitudinal studies, it can be very challenging to keep a position in the minds of residents unless the routine is soundly established in their schedule and mind. As many suffer from dementia and have poor recollection of people or faces, a resident would forget the face of the researcher, or the purpose of an arrangement made prior, on multiple occasions during the studies. Being part of their everyday life routines to the extent of being considered a part of the everyday actions is very constructive for many aspects of this type of research. It relates to residents being confident that social interactions will be pleasant and respectful has shown noticeable differences in the type of working relationship possible within the user group.

Another crucial way to keep focus is through a clear and constructive relationship to personnel. For longitudinal studies, it simply heightens the probability for support of the agreements made with residents for various study procedures, as well as performing practical tasks such as noting measures, etc., under circumstances where the research team not present at the nursing home. Perhaps even more importantly, the critical relationship between researcher and residents (which will be addressed later) goes partly through the personnel as well. Personnel essentially work as a gateway to be accepted by the residents, both directly and indirectly. The direct part is to introduce the affiliation of the researcher and the nursing home towards the residents. Personnel often have the trust of the residents, who will accept foreign people if they are clearly trusted and introduced by the personnel. Indirectly, the residents also observe many things, for instance the relationship between the personnel and the research team. Residents have described using this as part of the 'measuring stick', to evaluate whether a researcher was initially someone they want to interact with.

5.3 Establishing and maintaining a routine

Nursing homes like Akaciegården are much about rhythm and habit. Every day has a standard operation schedule (morning/evening assistance for individual residents, meals, etc.), and every week has a repeating activity schedule for specific weekdays, such as bingo, singing class, physical therapy, rhythmic gymnastics, the in-house hairdresser, a beautician, etc. Nursing home living thereby follows a recognizable pattern, which residents should be able to comfortably learn and rely upon. In addition, singleton events such as concerts, movie viewings, or various celebratory/traditional events occur on a regular basis throughout the year. Such general format for week schedules is necessary, as residents with decreased memory/cognitive capabilities are challenged even when navigating such recurring schedule. In addition, singleton events are not in small quantity per year. And while residents enjoy them, some need personnel to help keeping track of the activities interesting to them.

When performing especially longitudinal studies with residents, it is crucial that resident participation is structured, so that it becomes part of the fixed weekly rhythm. Otherwise, there is a high risk that they will forget or not enable themselves to go, because they might need help to get to the physical therapy and either won't ask (out of politeness) or simply cannot get help from the resources of personnel at a given time. A routine needs to be established around the group of residents who have agreed to participate as subjects. It thus becomes necessary to involve all personnel affiliated with each individual resident participating, and make detailed arrangements and agreements concerning each individual resident's study procedure activities. Residents regularly need personnel to remind them of their daily activities, and the study procedure needs to become part of this routine.

It even became necessary to schedule when individual subjects would be able to access the manuped, simply because of an overweight of subjects initially (and randomly) wanted to use the single available manuped device at the same time each session. To ensure the procedure to run smoothly, access to the manuped for residents was then scheduled into specific time slots, so certain divisions of residents had access to the manuped, at least on certain days, at least in certain time frames. Of course, none were unwelcome at any time during physical therapy hours, but typically residents would follow a routine given to them, and not deviate too much. Setting up such type of longitudinal study at nursing homes involves a surprising amount of people, besides the administration for permission and the physical therapy team working at the clinic. The nursing home facilities used in the studies are split into 8 separate departments. The group of residents used for the studies were spread on 6 of these departments. Each department has individual teams of personnel, and each team has changing shifts, substitutes and volunteers, whom all need to be informed to ensure that the routine is running every week. Each department needs to know which of their residents need to go and when, and make sure to fit this into their schedule concerning preparing and aiding the resident with clothing, baths, etc. outside the research schedule.

Besides having personnel assisting residents to uphold the scheduled research activities, residents' general connection to their participation agreement seemed to benefit as well from exposure to various types of paper media. A3 posters with images of the recreational VEs and a member of the research team with the physical therapists (as seen in Fig. 6) were placed in all central traffic areas inside the nursing home, serving as a constantly occurring reminder for subjects on their daily tours round the building. In the monthly (in-house) nursing home newspaper, a page was dedicated to the purpose of the project, using short text and large pictures (see Fig. 7). Many residents to add to their awareness of the exercise initiative confirmed this. In conjunction, it was important for the research team to be present and visible at the nursing home as much as possible, despite not always having an active role in the data gathering.

Figure 6 - A3 Poster placed at all common areas to help residents remember their engagement

5.4 A trusting relationship

No matter the methodology, studies that require inter-personal interaction of any kind with nursing home residents will include a variable degree of qualitative aspects. Whereas this inter-personal interaction might not be directly linked from the empirical aspects of the research, it is very difficult to separate the person and the subject participation, when working with residents.

According to Truglio-Gallagher, et al. [19], a personal relationship between researcher and subject is fundamental for qualitative inquiry with older adults, and most advantageously obtained through the establishment of trusting relationship between older adults and researcher. As qualitative approaches such as questioning, conversation or interviews invites for replies to inquiry, the quality of subjects' responses, meaning the quality of insight into the older adults' experience, obviously depends solely on the willingness of respondents to converse and share their experiences [19]. But whether or not the method is in fact qualitative, a trusting relationship and faith in the researcher is vital for the sheer possibility of retrieving information, as showed from the previous example, where the collection of quantitative data had to be conducted through a (for residents) demanding, pseudo-qualitative interview approach. Their hardship and effort in completing the cumbersome quantitative responses, clearly supports the notion from Truglio-Gallagher, et al., on how trust and faith between the parties are essential for any meaningful communication, partnership and quality of data with older individuals [19].

Kære beboere på Akaciegården

Hej! Jeg hedder Jon. Nogle husker mig måske fra tiden på Skellet, hvor jeg var ude hos jer over nogle omgange. Nogle af jer prøvede i den forbindelse en lidt anderledes måde at opleve træningscyklen nede hos fysioterapien.

Jeg har været væk siden (er bl.a. blevet far igen), men er nu tilbage, og vil gerne prøve nogle nye ting sammen med de af jer, der har lyst. Det bliver hyggeligt! Det bliver med cyklen igen, og kommer til at handle om hvordan det føles (for jer) at cykle hvis man samtidig får mulighed for at opleve at køre igennem forskellige landskakber imens.

Underneden I kan se et lille smug-kig på de landskaber det bliver muligt at cykle igennem.

SøPark

FriLandet

BjergTop

VinterSkov

Hvis det er noget I har lyst til at prøve, så snak med Maja eller Neel i fysioterapien. Og så ses vi engang i Februar!

Jeg glæder mig til det! Mange hilsner, Jon.

Figure 7 – A4 Page from the in-house newspaper

5.5 Personal boundaries

During the described studies, the trusting relationship to residents sometimes meant the difference between subject participation or not. Residents with whom it was not possible to build a personal connection or a type of social comfort, were difficult to recruit as subjects, and if recruited, showed low engagement into the routines. They also displayed very limited willingness to share their experiences when asked. Residents with whom it was possible to build a personal connection, showed the opposite traits.

According to Haal, et al., trust can generally be regarded as the "*the optimistic acceptance of a vulnerable situation in which the trustor believes the trustee will care for the trustor's interests*" [20]. For older adults such as nursing home residents, vulnerability is a central phenomenon due to their gradually increasing physical and mental limitations, and thereby overall frailty [21], and a relationship depends on the inherent knowledge that they will not be harmed, by the impression of the good intention of the other person [19], and researchers must place careful attention to how they are to 'connect' to residents [22]. Connecting is not trivial, as individual residents have a varying degree of curiosity or acceptance to new elements in their everyday routine, which ranges from very open minded, to very cautious and alienated. Being mindful of the personal boundaries of a resident can prevent unfortunate situations, where a personal space or boundary is overstepped. It much depends on the personal situation of the individual resident (private life, illness, death of a friend, etc.), but to a degree, which was not initially considered sufficiently during the studies.

Moreno-John, et al [23] point out in their literature review on trust relating to older adult participation in clinical research; how many groups of older adults have a general mistrust to the healthcare system as well as researchers, in addition to some older adults showing reluctance to sign consent forms [19]. The research team representatives was not initially aware, and thus did not consider this in one situation, where a female resident was asked to fill out a letter of consent. A signature would simply allow us the usage of video footage of her verbal and behavioral responses, exclusively for transcription purposes. When presented with the document for signature, she looked at the researcher with fear, took distance and expressed that she would not sign or further participate - and that she would now like to be left alone. After the situation had played out, staff gave background into how this particular resident had just placed a series of signatures for power of attorney, for her family home to be sold and most of her belongings to be taken to storage, only a few days before. This had left her very sensitive to formal documents, and people who wanted to intrude her personal life with demands and restrictions of freedom over her property. In reference to the above quote from Hall et al [20], is clear that this particular situation had no optimistic acceptance with the so-called trustor of the interests of the trustee, leaving the resident feeling exclusively vulnerable. The example illustrated the importance in creating a comfortable and trustful social space between researcher and residents, before initiating active processes or making direct requests. Introducing the written consent too early in the process resulted in mistrust and a loss of a subject for further studies. It will never be known whether the just described situation could have been avoided, but the experience served as an onwards reminder to remember, to patiently develop a personal connection to residents before proceeding to personal requests or commitments.

5.6 Establishing a connection

Trojan and Yonge recommend investigators to think carefully about how to connect to potential participants [22], and in the case of the nursing home, establishing a personal relationship was eventually found not to be very complicated, but require time and personal investment. In the beginning, it was found to be very difficult to approach residents and make simple, meaningful conversation. In hindsight, this was primarily due to generation-cultural differences (such as choice of language and terminology, as well as conversation topics and rhythm). Becoming accepted to a degree where individual residents would open up to a researcher, took very different amounts of time of obtain. Depending on the individual, this could literally take between minutes and months. And due to certain "less accessible" residents being obvious choices as subjects, some of the long periods spent to create a personal connection were deemed necessary. Gilson points out how inter-personal trust evolves over time [24]. A substantial amount of effort to be present and visible at the nursing home was therefore placed into activities such as participating at the physical therapy center, in planned social events, visiting residents at their private apartments for a casual chat, or bringing family (kids) to the nursing home, in the attempt to become familiar face. The many hours spent allowed a lot of social interaction and personal connection. There is no doubt that ever since, making conversation, asking for participation, or conducting studies felt natural, and became significantly easier in relation to acquiring subjects, requesting their time, making appointments and retrieving information.

Spending time at the physical therapy was necessary and insightful in many ways for the purposes of understanding the rhythms, capabilities and limitations of the residents in an exercise-oriented context. However, for building personal and trustful relationships, the most constructive place to do so was at residents' private apartments, clearly being the location inside the nursing home, where most residents tend to feel relaxed and comfortable. In addition, apartments had a useful application when performing the first couple of visits, as some residents would not contribute much in the beginning of sessions, not yet knowing the researcher or procedure well. Most private apartments had many objects of meaning to the resident, such as images of grandchildren, or other possessions of personal significance. If the initiating conversation (for instance before the start of an interview or questionnaire) did not fuel itself naturally, such objects were extremely well suited conversation starters/topics, sometimes resulting in long conversations. In these cases, such topics gave residents a sensation of good intentions and focused, personally directed interest elicited by the researcher. The result was most often a strong foundation for further conversation, and leeway into research related topics. This conversation environment was presumably reminiscent to what Truglio, et al. calls the "cornerstone in all qualitative studies" [19], being the point where trust is completely established and present, for proper dialogue to take place. With most residents, this was typically marked by a certain "critical" point, from which they will start talking and telling stories almost endlessly. Not only (and sometimes almost not at all) in relation to responses on asked topics or items, but past life stories, thoughts, inquiries to the researcher, etc. It would not be uncommon in this situation, to almost have to struggle for speaking time for the researcher. In short, some residents have a barrier that needs to be ‘broken down’ gradually, respectfully and patiently by personal engagement from the researcher, into whatever captures their interest of conversation. After a certain time spent together, it has been the experience that most residents happily accept the relation, and thereby have become ready to partake in most interactions or challenges later proposed by from the researcher. To the experience of this author, the personal relation is *the* central aspect to achieving leeway for the research collaboration.

To fully appreciate the rationale behind this, it is important to remember the context of the nursing home, in terms of why the impression of an honest, personal engagement and interest with the residents has value to them. The nursing home, for all its merits, can be an extremely lonely place for many residents. While a certain group of the residents have (the luxury of) actively visiting family and friends, many do not. Friendships do establish themselves between residents, but are subject to a combination of high risk of illness, high level of cognitively limited residents, and the frequent exchange in residents at the nursing home. When approached, many cognitively capable residents really like a meaningful dialogue whenever they can get one; meaningful in this context is (as described above) personally directed, attentive, interested and respectful. In the context of their everyday life, it is the impression that this is one of the things to which many residents do not have access to the degree they used to have. And for the cognitively well functioning residents, the experiences from conversations leaves this seeming like a substantial loss of everyday value and meaning.

Once personal relations are properly established, there are very few things this user group will not do for e.g. a research group. The experience has been that if personally engaged residents are in any way capable of helping the researcher towards his or her goal, making the effort to form relations a desirable investment to the resident. The positivity of this engagement is elaborated by Truglio-Gallagher, et al., in how participation in research endeavors is able to provide some older adults a personal learning exercise, as well as a sense of importance from the personal role they play, providing a service and contribution which benefits others [19]. This has been recognizable throughout the project, by a sense of personal pride with certain resident individuals, from their contributions to the studies. A typical scenario would be a resident greeting the researcher, eagerly describing how many times or how long (etc.) the individual resident had been exercising with the augmentation since last time the researcher and resident had last seen each other. Or how the resident could actually feel a physical improvement since beginning the exercise routine anew, from following the established participation schedule.

5.7 The difficult conversations

There are some aspects to the interaction with residents that a researcher (in the role suggested in this chapter) has to be aware of and prepared to handle. For many reasons, the context of the nursing home also somewhat signifies conclusion for many. It is the last place they will most probably live, if not for a hospital in the very end. It is a place they *have* to live, because they or their relatives have shown incapable of properly maintaining an independent lifestyle. And for many, it is a place they live because they have outlived their contemporaries, amongst those partners or even children.

The nursing home lifestyle serves as constant a reminder of this, not only due to the change in environment from their life as it previously was, but due to the nursing home environment. The sheer amount of people partly or completely sharing this lifestyle is substantial, and could possibly serve as an overwhelming reminder of a specific individual's situation. As such, many residents find them selves looking backwards more than forwards. At this advanced age, the combination of social isolation and loneliness, as well as comprised functional ability, leave many residents very vulnerable at times [19].

In the process achieving or maintaining a personal relationship through conversation, some residents pose the unique challenge of intense conversation topics concerning loss, death, and loneliness. Insights provided by senior nursing home personnel, such conversations are very important to the residents. Thus it is necessary for anyone who has ambitions to be a meaningful person for a resident, to fully submerge and engage into these conversations. Its importance was further highlighted by the notion that such conversations are not possible that often for the residents, as many social and health (Sosu) assistant personnel deviate from these topics when confronted. Despite most likely wanting to help residents, many Sosu assistants are simply not personally equipped to handle such comprehensive conversation topics. Engaging in such conversations in the role of a researcher can make a real difference, for the purposes of establishing or maintaining personal relations. They *will* arise with most residents, and it is important to make the choice early on, to not refrain from the subject matter when it arises.

5.8 Advancing with VE technology

One of the challenges with initial studies was for residents to participate with unknown and exotic technology, being unsure of whether they would have the necessary skills or perform as expected. Explaining the setup and making agreements with a majority of the residents was therefore not trivial. When initiating the studies, many residents needed much time to get familiar with the technology and VEs. Similar to establishing personal relations with patience, introducing technological advancements would need to happen slowly. This was the reason the studies presented in this paper were performed using an LED TV, instead of using a Head Mounted Display (HMD). The HMD would almost certainly provide a more immersive and convincing experience of being inside the VE. But it was feared that pushing technology too fast would overload residents' upper threshold for novel technology experiences per time.

Over the course of the 4-month study, many residents developed a relationship to their favorite VEs, as well as a good relationship to the VE augmentation system. Increasingly positive attitudes towards the augmentation were seen from residents. In periods where it has been shortly unavailable, residents have asked if they could get it running again soon. This has aspired confidence in relation to commencing with HMD studies, now that residents are experienced with the VEs, and confortable with the LED TV based exercise augmentation.

5.9 Gathering data

The items from the Intrinsic Motivation Inventory (IMI) were in one of the studies used to measure the level and orientation of the motivation effect of the VE augmentation of the manuped exercise. However, using quantitative measures with nursing home residents was found to be a substantial challenge, and will not be replicate in future studies, if avoidable. First and foremost, written generally conflicted with often occurring instances of compromised vision for many residents, where small letters would be practically invisible, not to mention that some residents was actually lacking the ability to hold and place a pen to set their cross. What showed to be a central challenge however, was how most residents were conflicted by the arbitrary nature of placing their rating.

In the IMI questionnaire, items are statements to which subjects need to state their level of agreement to, corresponding to a 7-point Likert scale, (1 corresponds to "not true at all", 4 is "somewhat true" and 7 corresponds to "very true"). While this method could seem straightforward to most, many nursing home residents, with the variance of cognitive limitations between them, seemed to severely limit their ability to fully comprehend this, perhaps slightly abstract concept. Only very few residents were able to fill out the form by themselves. Almost all residents required assistance from the present researcher, who was forced to adapt and read the items aloud, and subsequently try to conceptualize and step-wise isolate a correct answer. An example would be, having to read an item aloud and asking, "*would you say that you agree or disagree?*" Depending on the answer, the procedure would lead to a follow-up question such as "*so would you say that you completely agree, or only somewhat agree*?" A last follow-up question would be "*so, would you say that you lean towards better or worse than (answer)?*" In practice, the 17 IMI items would most often transform from a written form into a structured interview guide for the researcher, conducted through verbal conversation. In this adapted form, the response sessions were highly uncomfortable for both researcher and resident, due to how a verbal depiction of something quantitative is a challenging exercise. Based on this experience, the advice concerning this user group and data gathering would be to keep to purely qualitative methods, at least in anything related to user responses. In addition, qualitative measures, which encompass any sort of interview, speak to the residents' desire to partake in conversations and have another moment to share their life story to someone who genuinely wants to listen.

6 Conclusions

This chapter has looked into various conditions relating to the lives of nursing home residents, predominantly through the search for an explanation for why many residents lack the desire to perform regular exercise, despite the obvious benefits. It has described the circumstances for the choice to either exercise or not, and presented one suggestion to a solution, in the form of the VE augmented manuped exercise. The new manuped form sought to satisfy a need for short-term entertainment, to complement the long-term benefits of the exercise. It also provided an immediate feedback to the exercise actions, which gave a different sense of purpose to the exertion of the exercise, among other things. Besides that, the chapter suggests that the augmented manuped experience offered something not found in other regular nursing home activity offerings, which was the ability to travel to another place, and see and experience recreational landscape environments otherwise impossible for the residents to experience. The second part of the chapter looked into more circumstances and characteristics of the nursing home environment, seen from a researcher's perspective, in term of some concrete challenges and experience-based suggestions to constructive approaches to constructively improve the chances of success, when performing research with nursing home residents. There are many obstacles, but also many constructive solutions, which should be able to ease the working conditions of the researcher, as well as making the collaboration a better experience for the nursing home resident.

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CHAPTER 12. PAPER V. GOING OUTSIDE WHILE STAYING INSIDE – EXERCISE MOTIVATION WITH IMMERSIVE VS. NON-IMMERSIVE RECREATIONAL VIRTUAL ENVIRONMENT AUGMENTATION FOR OLDER ADULT NURSING HOME RESIDENTS

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ABSTRACT - Virtual technology and immersive experiences are not very often associated with older adults. Recent studies suggest that exercise augmentation using flat screen-based virtual environments, which allow nursing home residents to experience virtual places different from the nursing home, can increase the intrinsic motivation of nursing home residents. In this paper, we increase the immersive properties of such augmentation through an Oculus Rift Head Mounted Display, to evaluate the effect on the older adults' sense of presence, if it has any relation to the level of intrinsic motivation to exercise, and an effect of the exercise user experience.

Key Words: Older adults, exercise, motivation, virtual environments, augmentation, presence, immersion

I. INTRODUCTION

Besides its role as an entertainment platform, virtual reality (VR) undoubtedly has potential for many serious applications, such as motor rehabilitation for individuals with disabilities, post-stroke rehabilitation, Parkinson's disease, balance training, gait rehabilitation, etc. [1] [2] [3] [4]. Some of the strengths of VR applications are found in the ability to facilitate simulation of contexts that promote real life behavior [5]. They also promote safety and control in otherwise unsafe contextual conditions, which allow particular target group practitioners to develop or rehabilitate skills without the real life risks [6] [7]. According to Slater [8], VR can be categorized as immersive VR (IVR) to the degree that the technology portraying a virtual environment (VE) delivers stimuli to all senses, and tracks or transfers a user's behavior into and onto the VE. A regular, small desktop PC monitor with no tracking would in most cases be characterized a low immersive system, for instance, compared to a Head Mounted Display (HMD) with orientation tracking. Low immersion VR seems applicable with older adults, as recent studies have shown how augmenting a manuped exercise (chair-based exercise bike, as seen in Figure 1) with recreational VEs can be used with nursing home residents for motivational purposes to exercise [9] [10]. These studies utilized a setup with low immersive properties (an LCD monitor as the visual display, no tracking).

Figure 1 - The manuped exercise bike.

Despite the low immersion display, participants reported an increase in intrinsic motivation to exercise. Qualitative responses relating predominantly to how their activity translated convincingly onto the behavior in the VEs, how they experienced being able to "travel to a place outside the nursing home" and that they were intrigued with exploring the recreational VE content while exercising. With a higher-level immersive technology, such as an Oculus Rift HMD for visuals, a users' sense of being present inside a VE, the translation to their actions and their ability to explore should theoretically increase. As a consequence, this should also enhance their exercise motivation. This paper investigates the effects of increasing the immersive properties of such exercise augmentation, in particular, whether it changes the sense of presence inside the VE, how this translates to the overall exercise experience, and whether it has any effect on their reported intrinsic motivation to use it for exercise.

II. BACKGROUND

Many nursing home residents lack the physical conditioning that allows them to live independently, even to the degree of performing everyday tasks, such as getting dressed or eating independently. Dependence on others affects their overall life quality [11], but general physical exercise can rebuild the strength and coordination needed for many of such everyday functions [12], and improve upon areas as sarcopenia, cognitive performance, and mood [13]. Nursing homes typically provide access to an in-house physical therapy facility, where professional physical therapists structure individual programs for each resident. Despite this, many residents do not exercise sufficiently to maintain functional independence. At Akaciegården Nursing Home in Copenhagen, the most frequently used exercise routine for residents is a manuped; a chair-based, indoor exercise bike for arms and legs (see Figure 1).

The manuped can allow a broad spectrum of exertion, and is safe for residents to use without assistance. Meanwhile, the conventional manuped exercise experience is an experience of statically facing a wall for 10-50 minutes, performing an activity that by residents describe as trivial, boring and often physically painful [9] [10]. The same tendencies can be found in rehabilitation literature [14] [15] [4]. It suggests that VR might a) provide alternative feedback to the exercise actions, b) bring increased and diversified stimulation to the experience by informative, interesting or engaging experiences and c) distract attention from e.g. exercise-related pain. All of which can lead to increased motivation towards an activity [16] [17] [18] [19] [20].

In recent studies [9] [10], the augmentation of the manuped exercise allowed users to ride a fixed path in a recreational VE while pedaling the device. The augmentation provided audiovisual feedback, with VE visuals designed with Unity3D 4.6 Pro, displayed on a 46' LCD screen, and a stereo audio display (headphones in the first study, 2.1 Logitech speaker system in the second study). An Arduino UNO connected to a Hall Effect sensor + magnet were used for tracking pedaling. A system setup overview is shown in Figure 2.

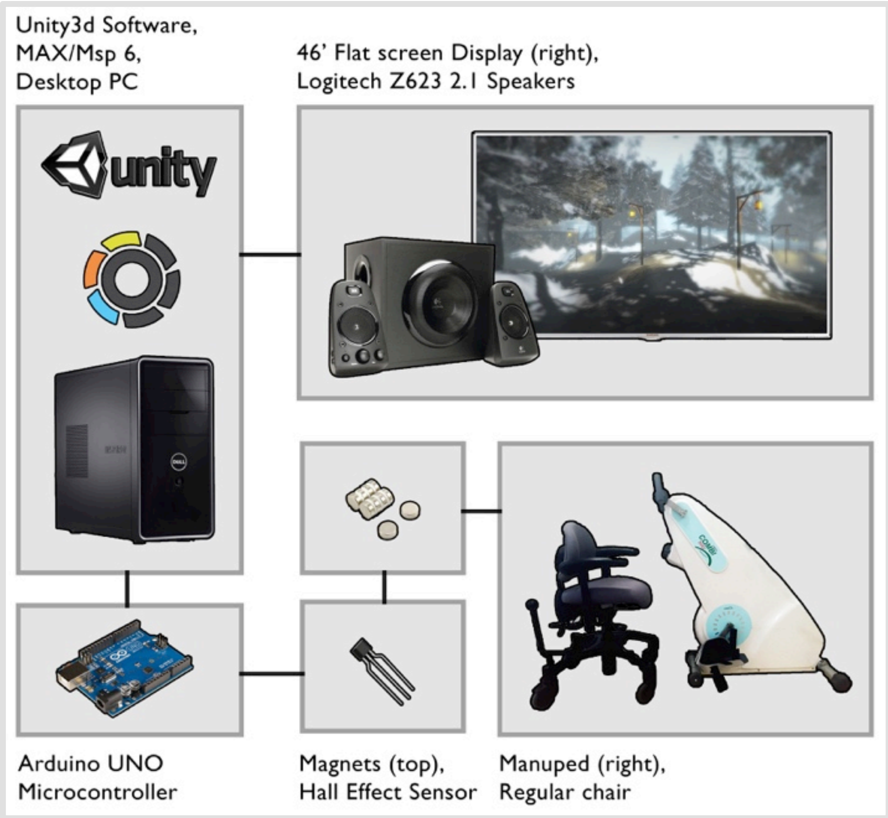

Figure 2 - Overview of the system setup for the exercise augmentation.

Results from the first study showed strong indications of a general enthusiasm towards the VEs as part of the exercise [9], which justified a subsequent, longitudinal study [10]. Over a 4-month trial period, the second study had residents given access to four larger and more complex VEs to explore while exercising. The study measured various factors of intrinsic motivation based on the Intrinsic Motivation Inventory (from the Self-Determination Theory framework by Ryan and Deci [21]), before and after implementing the augmentation. Five intrinsic motivation factors were measured, with results suggesting a singular, but definite increase in the intrinsic motivation factor of Interest/Enjoyment [10].

In the life of many nursing home residents, individual factors (such as physical or mental conditions) often limit free access to the world outside the nursing home. Besides the qualitative responses already mentioned results from [10] suggested that the augmentation contributed to the desire to exercise longer, with more effort, to decrease attention to pain and minimize the focus on the exercise duration [9] [10]. Reported experiences such as 'using more power when going uphill' [10], despite no exertion variance in the system depending on e.g. slopes in the VE path, suggests some degree of mental transportation into the VE. With a study already suggesting to measured the intrinsic motivation for this context by the factor of Interest/Enjoyment, the usage of this will be repeated in the method in this study. In the following, we will look more into the theory and tools to increase Interest/Enjoyment for the augmentation.

A. Immersion

The term immersion has several conflicting theoretical approaches. On the most general level it is possible to distinguish between immersion as a psychological phenomenon [22] [23] [24] [25] or as a property of technology, which is the direction focused on in this paper. Notably, Slater argues that the degree of (technological) immersion corresponds to the extent to which a technological system *"[...] delivers displays (in all sensory modalities) and tracking that preserves fidelity concerning their real-world sensory modalities*" [26]. To provide an illusion of reality inside the virtual domain, an immersive virtual reality (IVR) system should optimally consist of visual, auditory and haptic displays, combined with tracking, to support multimodality similar to that of real world interactions [8]. However, IVR systems often support less than every such display at the same time. According to Slater, IVRs can (for instance) be characterized by the sensorimotor contingencies (SC) they support, which to an IVR are the "*set of valid actions that are meaningful in terms of perception within the virtual environment depicted*" [8]. The valid actions a user can perform inside a VE result in changes in perception of the VE (valid sensorimotor actions), or changes to the VE itself (valid effectual actions) [8]. Slater proposes that immersive systems can be differentiated and organized from lesser immersive systems in terms of if one system can simulate system (you can simulate a monitor on an HMD, but not vice versa) [8].

B. Immersive system characteristics

Looking specifically at Slater's definition of immersion [8], the parameters that determine the quality of an IVR experience include a) graphics frame rate, b) the extent of the tracking, c) tracking latency, d) quality of the images (e.g. color, spatial, contrast resolution), e) field of view (FOV), f) visual rendering quality (geometry and lighting realism), e) dynamics (behavior of the diegetic objects in the IVR), and f) the range/fidelity of sensory modalities accommodated [8]. Slater presents no particular classification or grading framework of the level of immersion of a certain IVR system, but individual systems might be comparable regarding where they might be equally or differently immersive [8].

C. Presence

In the ‘response-as-if-real’ RIAR framework by Slater, the immersive properties of a system, the sense of body ownership, and two perceptual illusions of place or plausibility is what supposedly combine to make individuals respond realistically to virtual worlds [8]. In more detail, the place illusion (PI) refers to the sense of ‘being there’ in the virtual place, even despite if being consciously aware that one is not. According to Slater, the PI depends primarily on the range of normal SCs used inside the IVR (whereas the immersive properties are the SCs possible inside the IVR). The plausibility illusion refers to when events in the virtual world feel or appear as if they are indeed occurring, despite one being aware that they are not. Central aspects of such components are that they occur or happen independently of the user, but address or refer directly to the user, for instance, a virtual animal reacting to you [8].

D. Measuring Presence

There are numerous measuring methods to presence, for instance, self-reported measures [27] or behavioral measures [28]. The Slater-Usoh-Steed (SUS) questionnaire is a self- report measure introduced by Slater, Usoh and Steed in 1994 [27], is widely used as a presence measure instrument, and has been revised several times [29] [30]. The items cover three themes; the sense of being in the VE, the extent of which the VE becomes the dominant reality and the degree to which the VE is remembered as a place. The first version of the SUS had three items, whereas later versions had 6, each as a 1-7 semantic differential scale relating to the particular item, with the higher scores indicating higher presence. Scores of 6 or 7 represent the sense of presence, and an overall ‘presence score’ is thereby determined from the amount of presence representing scores out of all possible [30].

E. VR Sickness

A potential issue of introducing HMD technology to the elderly audience is the notion of VR sickness (also referred to as simulator sickness or cybersickness). VR sickness is a state similar to motion sickness related to HMD usage, with symptoms such as oculomotor disturbances, headaches, nausea, sweating, fatigue, or disorientation [31] [32]. Considering typical causes of VR sickness in design matters, as elderly (age 64+) users tend to exhibit strong reactions, for instance, specifically concerning high rotation speeds and exposure time [31]. VR sickness typically occurs when a retinal slip (visual image moving across the retina) triggers a vestibular response, but fails to achieve alignment [33]. A contributor to this effect is FOV, as the eye periphery is predominantly responsible motion perception [34] [33]. A decreased FOV can minimize (but not eliminate) the VR sickness effect, but studies also show that a small FOV reduces the sense of presence [25] [32] [34]. For this study, FOV should not be decreased, as facilitating presence is desirable.

Measures to limit the potential VR sickness can be to minimize rotation speeds, ensure a (system-wise) high precision, low-latency tracking [33], high frame rate rendering and short persistence displays [32]. This study will not measure VE sickness, but inquest participants for signs of nausea or disorientation [31] to limit potential overexposure.

III. METHODS

As previously mentioned, the goal of this study was to measure the effect on the user experience and exercise motivation, when increasing the immersive properties (as defined by Slater [8]) of the augmentation. Increasing the immersive properties of a system should enhance the potential of an increased sense of presence inside a VE. Seeing as one of the central aspects to the augmentation experience for residents has been the experience another place and its contents, an increased sense of presence and ability to explore the VE content, could very well improve these aspects of their overall experience. Such improvement could show on their reported level of intrinsic motivation (to exercise) and in the overall exercise experience with the augmentation.

The participant group was residents with prior experience with the existing augmentation (Figure 2). Based on this experience, participants were asked to rate their intrinsic motivation to exercise with the augmentation, as well as their sense of presence inside the VEs when exercising with this version of the augmentation. Besides, participants were asked to try a more immersive version of the augmentation, and requested to rate their experience with the same presence and motivation items. The two conditions varied by a) their visual displays and b) the support of SCs related to these displays (to be detailed more in System Setup). Onwards, condition A (cA) is referring to the setup already installed at the nursing home (Figure 2), using a 46’ Samsung TV (and no orientation tracking). Condition B (cB) is referring to the same setup, only using an Oculus Rift Developer Kit 2 (with orientation/position tracking) as the visual display.

The study was thus not a classic comparative study. The particular approach was chosen to minimize the mental requirements with participants, and to utilize the knowledge already obtained by the participants (see [9] [10]). Allowing participants to recognize the VE readily, remove unnecessary energy required when experiencing and memorizing contents and contexts for the first time. Participants’ previous experience would hypothetically make it easier to recognize similarities between the two conditions, to decipher differences. As a side-benefit, the approach would shorten the duration of each participant session, which is a very central aspect of nursing home research.

A. Participants

Participants were chosen from a quota sampling approach, by consultation with the physical therapists, based on pre-specified characteristics such as a sufficient cognitive ability to experience and communicate experiences, sufficient physical strength and motor skills for the manuped, and adequate experience with the augmentation to be familiar and comfortable with the experience. Of the 150 residents at the nursing home, 15 residents were able to meet requirements and agreed to participate in the study. Of the 15, nine residents (9 female, average age 85 ± 10.2, age range: 69-101) were able to complete their sessions. Reasons for non-participation were illness, progression of cognitive limitations, deployment to another nursing home facility, and death. Before the sessions, the nine participants had been using the aforementioned augmentation between 2 to 10 months (average 7.2 ± 3), with between 4 and 39 prior cA exercise experiences (average 17.1 ± 12.2).

B. Quantitative Measures

To measure the sense of presence and the level of intrinsic motivation, participants were asked to rate respectively three SUS items and four IMI items for cA and cB. The order of the SUS and IMI2 items for each participant, for each condition, was randomized using a simple random sequence generator. In an attempt to counterbalance despite the small sample size, 5 participants were asked to rate cA first, and 4 participants were asked to rate cB first. All SUS and IMI items were translated into Danish, and adapted from [30] to the context of the VEs, before being used in the sessions. The SUS items used in the sessions were:

- Please rate the sense of being in the landscape, on a scale from 1 to 7, where 7 represents your normal experience of being in a place. *I had the sense of "being there" in the landscape: (1) not at all. (7) very much.*
- To what extent were there times during the experience when the landscape was reality to you? *There were times during the experience when the landscape was the reality to me (1) at no time. (7) almost all the time.*
- When you think back about your experience, do you think of the landscape more as images you saw, or more as somewhere you visited? *The landscape seems to me to be more like (1) images I saw. (7) somewhere I visited.*

The IMI items are statements, to which a participant can express his/her agreement or disagreement, rated on a 1 to 7 scale, with values representing *(1) not at all, (4) somewhat true* and *(7) very true*. The four IMI items used for the study (from the intrinsic motivation factor of *Interest/Enjoyment*) were:

- *I enjoyed doing the bike exercise with the landscape very much.*
- *I thought the bike exercise with the landscape was a boring activity (*reverse score).*
- *To perform the bike exercise with the landscape was fun to do*
- *I would describe the bike exercise with the landscape as very interesting*

The particular IMI factor of Interest/Enjoyment was chosen based on a recent study [10], where it was the one prevalent indicator of changes in intrinsic motivation for residents with the setup used in cA. With all items repeated twice in each session, it was decided not to include more items from respectively SUS and IMI, to minimize the session duration and mental load on the residents. Combined with the physical and cognitive demands from using the HMD, the affiliated physical therapists deemed this combined procedure to be the limit of the average resident's performance.

C. Procedure

All sessions were conducted in Danish, and performed in the physical therapy clinic, being the natural environment of residents' normal exercise routines, during regular opening hours. Physical therapists and other exercising residents were present during sessions, to keep the session environment natural and casual [35]. All session durations were noted. The order of whether a session would begin with SUS and IMI items for cA or cB was chosen by the order in which the participants were able to partake in the study, merely switching the order per participant. Before embarking on an HMD trial, participants were free to choose one of the four VEs inherent to the augmentation: Country Side, Mountain Top, Lake Park and Winter Forest (for sample images, see Figures 3-6). The choice of VE was based on personal preference for the individual participant. Upon choosing a VE, the Oculus DK2 head straps were adjusted to the head dimensions of the user and placed on the participant's head. As the VE showed in the HMD, the participant was given time to acclimatize to the visuals and asked to look around to show the orientation property. During trials, a small monitor mirrored the HMD's output, making it possible to follow the visuals given to the participant. The participant was asked to declare her readiness to bike. The researcher would place the participant's hands and feet on the handlebars and pedals of the manuped while verbally informing the participant of these actions. The trial would then commence until the participant wanted to stop.

All cB trials were video recorded using a GoPro HERO 3 as an observational tool for post-session analysis into the behavioral (verbal and nonverbal) aspects of residents' user experience with the HMD. Areas of interest were qualitative statements, to possibly contextualize the SUS and IMI items, relating to body language, exercise behavior, facial expressions (outside the HMD), signs of a sense of presence, interest in- or enjoyment of the VE experience, and immersive properties of the HMD technology. During the session with the Oculus DK2, participants were asked casually into their experience (example "how do you feel" or "how is it (the HMD) to wear"). While this could very well result in a break in presence, it was deemed necessary to make sure that participants did not sustain their involvement while experiencing VR sickness. Often, participants would autonomously initiate a conversation about the experience over the course of the trial. At the end of sessions, participants were asked to state their personal preference of either cA or cB, should they be forced to continue using only one of them, and motivate their choice.

D. Measurement Instrument Modification

With quantitative instruments as SUS and IMI, the participants had a hard time understanding the principle of the seven scale ratings and were practically unable to read and fill out a questionnaire (by a combination of poor vision, motor control and lack of energy). As a consequence, sessions were conducted in with the researcher becoming an interviewer, reading the items out loud for the participants. For participants having difficulties understanding the rating principle (all but two participants), the researcher would attempt to reach the closest approximation of their opinion as possible. The first step was establishing the direction of positive or negative, proceeding with asking into the degree of this direction, often in several stages. For example, if a participant would express general positivity to an IMI statement, the interviewer would proceed by asking whether they felt strongly about this positivity, or perhaps lean towards a more neutral-yet-positive opinion. At the end of the approximation process, the researcher would state the number that would be noted. The potential implications of the results from this procedure approach will be discussed in Section V.

E. System Setup

As shown in Figure 2, cA used a wall-mounted 1080p 46' Samsung LCD TV (model UE46F6515) with a 60Hz refresh rate – the same used in the previous studies at Akaciegården [9] [10]. cB used the Oculus Rift Development Kit 2 (Oculus DK2) HMD. As an HMD, the Oculus DK2 is a stereoscopic-capable binocular display, with orientation and (limited) position tracking, and a resolution of 960x1080 per eye, capable of running at a 75Hz refresh rate with a 100 degrees FOV. Both conditions used a similar hardware system with a desktop PC connected to an Arduino UNO and a Hall Effect sensor on the manuped frame, to track the pedaling of the user, from a magnet placed on the pedal arm. The software used was a build of the VEs created in Unity3d 4.6 PRO, with MaxMSP 6 runtime to receive input from the Arduino UNO and output data to Unity3d 4.6 PRO. cB was similar, only using the Oculus DK2 instead of the Samsung LCD TV, as well as a more powerful desktop PC to run the increased graphical demands of the HMD.

F. Virtual Environment Content Design

For the development of the four VEs, a design framework with a set of governing guidelines was used to try to ensure a structured approach to the design of such recreational, nature-based experiences, with a trail-based exploration directive in VR [36]. The guidelines are based on a variety of fields such as (but not limited to) tourism, urban design, landscape design and VE simulation of real world environments [36]. Examples of the VEs can be seen in Figures 3-7.

The four VEs were originally designed to compliment both a screen-based setup and an HMD configuration. The VEs would have to be interesting both when limited to a statically forward-facing camera (which recent studies suggest they succeeded with for residents [10]), but also have a VE design with sufficient content for meaningful HMD exploration, to transfer purposefully to such usage.

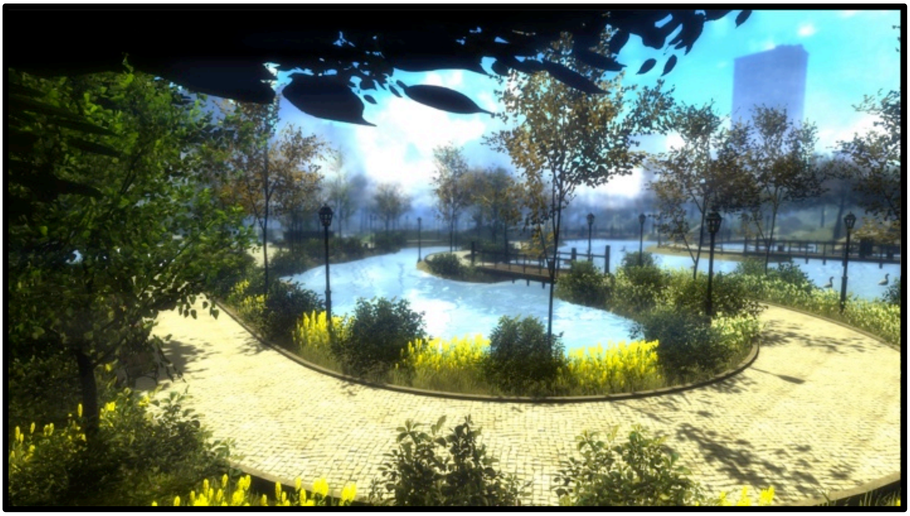

Figure 3 - Screenshot from the "Lake Park" VE; a large open area with brick-paved paths, central lake, pigeons and colorful/diverse vegetation.

Figure 4. Screenshot from the "Winter Forest" VE; a large, show-filled place with many twisty paths, routes and intimae areas.

Figure 5. Screenshot from the "Country Side" VE. A small cozy area on a single path; cottages, water, trees and a bird flock roaming the sky.

An example would be having individual objects/landmarks or dynamic events placed in various positions that would require the HMD freedom of orientation (e.g. upwards) to experience close hand. One example of this can be seen in figures 6 and 7, showing the same place in one of the VEs, where the experience of the site can change when provided an increased orientation freedom. When using the forward-facing camera of cA, a user will experience a small oasis inside one of the mountains (Figure 6). It is designed to be a unique location in the VE, sounding differently with no wind and reverberated bird sounds, and particular and narrow passages leading into it.

Figure 6. Screenshot from the VE "Mountain Top". Here showing a small oasis inside the mountain with a forward-facing camera.

Figure 7. The oasis from Figure 6. When using a HMD and looking up, a flock of birds will be playfully flying around.

The location is full of birds flying between the rock walls, but a user with cA (Figure 6) will never be able to see them, due to the inflexibility of the orientation.

Wearing the Oculus DK2 with cB and being able to look upwards (Figure 7), the oasis itself will unveil sunlight falling into the oasis and birds playfully flying around the oasis area in the flock or large wooden scaffolding constructions in one of the long passages leading into the oasis. Other examples of such events in the Mountain VE would be large man-made structures (buildings, bridges, etc.) or natural landmarks (waterfalls, rock formations, trees, flowers, etc.). With the expanded potential for SCs concerning cB, user responses to such events during sessions should provide indications to the degree that cB can indeed change such aspects of the user experience whether it possibly affects the sense of presence, and if such type of experience would be considered preferable to cA.

G. Immersive System Characteristics

The VEs were similar for cA and cB and thus should share many immersive system characteristics, as defined by Slater [8]. Meanwhile, there were some variations between the two conditions, due to the technology used, and its implications on the visual perception of the VE. These are outlined in Table I. Both conditions shared a lack of valid effectual actions, as the simple transition through the VEs is not considered causing a change to the VE itself, but merely a shift in position inside the VE. The conditions do however vary in the valid sensorimotor actions, as the Oculus DK2 allows the user to look around the VE by its orientation and position tracking. As such, the SC shared between both conditions was the physical operation (exercise activity) of the manuped device, whereas the difference in SC was the orientation and position tracking ability exclusive to the Oculus DK2 in cB.

TABLE I. Comparison of immersive system characteristics between conditions A and B

Immersive system characteristics	***Condition A***	***Condition B***
Graphics Frame Rate	Average approx. 40 fps	Average approx.73 fps
Tracking	No tracking	Orientation and (limited) position tracking
Tracking Latency	No tracking	Unknown (Not noticeable)
Quality of images	Seemingly better screen panel, with brighter colors and better contrast Not stereoscopic	Seemingly worse screen panel in terms of color and contrast. Stereoscopic
Field of View (FOV) (1.5 meters distance to 46’	Geometric FOV in Unity3d: 75 degrees	Geometric FOV in Unity3d: 106 degrees

LCD screen)	FOV LCD: 37 degrees (horizontal) 22 degrees (vertical)	FOV Oculus DK2: 100 degree (nominal) 106 degrees (vertical) 95 degrees (horizontal)
Visual Rendering Quality	Similar	Similar
Dynamics	Bird quantity higher	Bird quantity lower, due to CPU cost
Range/Fidelity Sensory Modality	Audio/visual sensorimotor display, with no body tracking	Audio/visual sensorimotor display, head orientation/position tracking

H. Forward Motion and Similar Perception of Speed

The perception of natural speed in IVR is deceptive. Perceived natural walking speed varies according to FOV (increases with smaller fields of view), and geometrically correct optical flow is perceived to be too slow [37]. Results in [37] showed visual gains reported as natural speed, to range between 1.5 and 2.0 with the Oculus DK2. When synchronizing the overall experience between cA and cB, this aspect of the development quickly became apparent, as the Oculus DK2 FOV for cB was considerably larger than that of the LCD setup for cA (see Table I; Field of View).

The findings related to natural walking speeds do not translate directly to correct forward motion speeds for biking locomotion in IVR, as walking activates provides proprioceptive feedback from many parts of the body, and about the actual movement across a surface. Much of this feedback does not exist in any similar fashion with a bike, as it does not allow direct proprioceptive contact with the surface. Nor does biking have any universal speed/exertion/pedal configuration due to gears, varying bike weight, and surface friction. As a consequence, the speed of both cA and cB were not set according to any objective measure, but merely to a speed subjectively deemed pleasant and slow, for each visual display. As cA had already been installed at the nursing home for months, the speed of cB was adjusted to give a speed sensation similar to cA. This speed adjustment was empirically tested and corrected internally over several iterations, before trying it on an actual participant. In this process, the speed of cB was slowed down more than initially anticipated, with the focus on limiting any danger of VR sickness with residents.

Considering the cognitive and perceptual limitations of these average older adult participants, the physical therapists' final evaluation of cB was that the added ability of orientation inside the VE while biking could easily overload residents if too much information would pass by (retinal slips), with too much speed. cB subsequently became five times slower at similar pedaling speeds, compared to cA. To the experienced pre-testers (authors), it indeed felt much slower (especially when looking straight forward), but to non-author pre-testers, cB still felt more intense due to the additional SCs of the Oculus DK2 display.

IV. RESULTS

Participant age, choice of VE, durations of the cB trials, and average exercise time with cA for each participant are seen in Table II. The average length of cB trials was 9.9 ± 6.8 minutes, while the mean durations each participant's prior activities with cA are 18 ± 7.2. VE choices are indicated with M = Mountain Top, W = Winter Forest and P = Lake Park. The Country Side VE was not chosen.

TABLE II. The age, VE choice, trial duration with condition B, and average exercise duration with condition A

Time spent (minutes) per participant with the HMD, Condition B									
Participant	1	2	3	4	5	6	7	8	9
Age	84	80	89	73	96	88	69	85	101
VE Choice	M	M	M	P	P	M	M	W	P
Duration *cB*	21	1	6	19	3	14	9	9	7
Duration *cA*	15	12	18	15	7	17	21	31	26

For cB participants were encouraged to exercise as long as they liked, but reminded to stop whenever they did not want to continue. Participant 2 had a very short run due to an unfortunate event at the beginning of the HMD trial, which will be explained in more detail later this section.

The average duration of cB sessions was two times shorter than normal cA session. However, 5/9 wearing the HMD for at least 9 minutes is acceptable for such high age [31]. Including interviews, rigging pedal straps, placing the HMD on participants, sessions typically lasted 10-15 minutes longer than the Oculus DK2 trial itself. Most participants were exhausted after the session.

A. Sense of presence

The SUS questionnaire results are predominantly interpreted by its *presence score,* which is the number *r* out of *n,* being is the number of questions posed [30]. In Table II, the mean scores for the three presence items are shown for *cA* and *cB*, with standard deviations. Below item averages are the presence scores for each condition, along with the standard deviation for all responses.

TABLE III. SUS items, averages, instances of R, and presence score for conditions A and B

SUS Presence Items		
Rating averages	**Condition A**	**Condition B**
Item 1	4.0 ± 2.6	6.0 ± 2.0
Item 2	4.2 ± 2.2	6.1 ± 2.0
Item 3	2.3 ± 1.4	5.9 ± 2.1
Instances of *r* out of *n*=9	**Condition A**	**Condition B**
Item 1	5	7
Item 2	4	8
Item 3	1	7
Presence score	**0.37 ± 2.2**	**0.81 ± 1.9**

From the results, *cA* have some representation of *r* ratings indicating a sense of presence, predominantly from participants who were asked about *cA* first and *cB* last (8 of 10 *r* rating for *cA* come from participants asked before trying *cB*). However, the *r* for *cB* is dominant, which can also be seen on the final *presence score* between the two conditions.

B. Intrinsic Motivation (factor: Interest/Enjoyment)

The IMI items indicating the degree of intrinsic motivation for the factor *Interest/Motivation* is calculated as an average of all the items for the factor. In Table III, the mean scores are shown for the four intrinsic motivation items representing the motivation factor of *Interest/Enjoyment,* along with the averaged factor score, for *cA* and *cB*, with standard deviations.

TABLE IV. IMI item averages and intrinsic motivation score for conditions A and B

IMI results	Condition A	Condition B
Item 1 (mean)	5.2 ±1.7	5.7 ± 2.0
Item 2 (mean)	5.2 ± 1.9	6.2 ± 1.6
Item 3 (mean)	4.1 ± 1.8	4.6 ± 2.6
Item 4 (mean)	4.8 ± 1.3	5.9 ± 2.0
Intrinsic motivation (*Interest/Enjoyment*)	**4.8 ± 1.7**	**5.6 ± 2.1**

The result in Table III shows an increase for cB, but the difference is below 1, which is not considered a substantial difference. Only the score for cB might be categorized as convincingly positive. A small sample size biases both results, which is addressed further in the Discussion section

C. Condition preference

At the end of each session, participants were asked into their personal preference of condition. Table IV shows the responses.

TABLE V. Condition preferences in relation to augmentation type

Preference of condition									
Participant	1	2	3	4	5	6	7	8	9
Condition	B	A	B	B	A	B	B	A	A

D. Observations

All cB sessions were video recorded (see: Figure 8), except Participant 2, due to an unfortunate event at the beginning of the session. During the procedure of placing participant 2's foot on the pedal, the magnet on the opposite pedal was accidentally positioned statically in front of the Hall Effect sensor. This made the VE camera accelerate quickly to a high speed, which severely frightened the participant. As the VE camera had decelerated, the participant agreed to another attempt, but quickly refrained from this, still affected by the very negative first impression. Due to the intensity of the situation, recording on the GoPro HERO3 camera was never started. Notes from the session were however written immediately after the short session.

Figure 8. Image from a video recording of a participant exercising with the manuped augmentation of cB.

The video recorded data underwent an analysis procedure of 'traditional coding' steps, as outlined in [38]. Steps are 1) *organizing* (transcription), 2) *recognizing* (e.g. concepts, themes, events), 3) *coding* (e.g. categorization, clustering) and 4) *interpretation* (e.g. analysis, theoretical implications) of the collected video data. The fourth step, *analysis*, will be in section V. *Discussion*. From step 1) *organizing,* 60 observations of non-behavioral behavior were noted, and 62 verbal responses were transcribed and translated from Danish to English. Step 2) *recognizing* and step 3) *coding* were merged in this process, due to all verbal response data being short and simple statements from the elderly participants.

Three categories were formed for verbal responses. *Overall impressions* are statements with no other content than opinionated statements to their enjoyment or lack of such. *VE Content* are statements directed at content-oriented experiences, and *IVR related responses* are statements indicating experiences of a sensation of presence inside the VE, or recognizing a difference in immersive properties compared to *cA*.

Four categories were formed for non-verbal data: *Body Language, Facial Expressions, Exercise Behavior* (e.g. speed, breaks) *and IVR/SC Behavior* (e.g. VE orientation activity, effects of the IVR technology). In the following, examples of verbal responses are presented, following the four categories. In the following, categories will be displayed by response exampling, to illustrate overall tendencies. Except participant 2, all participants gave verbal responses fitting the overall direction of the display.

Overall impressions: Of the 18 noted category responses, one was neutral *"This was a fine experience, but nothing special"*. 17 were positive, some referring to the experience as simply "*It's very good"* or *"This is quite nice, I think"*, some to enjoyable factors *"It is interesting", "Wow, we can quickly agree that this is very pretty", "It's peaceful", "Oh my, how funny is this??"* and some to the realism brought by the HMD *"It seems very real" "I mean, it's so natural"*.

VE content: The 15 noted responses swayed from neutral descriptions to positive content experiences. A neutral response example is "*There are the birds again"*. Positive statements were either directed at the content itself *"It's incredibly pretty with all those flowers"* or towards the fashion in which the HMD allows participants to explore VE content *"I'm noticing some new trees"*.

IVR related responses: Of the 29 categorical responses, many were descriptive on how the IVR experience is different from *cA*, many with positive connotations. In- session responses related e.g. to how participants were suddenly able to see new content by the orientation SCs of the Oculus DK2, *"There is so much to watch here!", "It's amazing to look at the birds"*. Other responses referred to the immersive effects of *cB,* indicating a sense of presence *"I feel that I'm driving around in here, I've never tried that before", "Oooh, now I'm getting dizzy (from looking over the edge)", "It feels like I'm really about to go down hill!", "Is that the real sun that you can see?"*. However, most responses in this category were given post-session, concerning the effects following the increase immersive properties of *cB "The sensation is completely different (from cA)", "To look at everything, this was easier here", "There was simply ...more", "You completely get the sensation what you were actually driving inside the landscape", "You are out in the middle of it all! Can you believe it?"*. Responses indicated an increased awareness of VE content and events *"With the glasses (HMD) it felt like more things happened" "But just the life that is around you, compared to the other (cA), I think", "You almost feel that you need to move your leg (not to hit a plant or branch)",* with some responses suggested positive experiences *"This is what I've been wanting all along", "When you look around, you forget that you are exercising. You just follow what is going on"*. Signs of the immersive properties of the system also showed when participants had the HMD removed *"Wow, what a turn of events" (removing the HMD), "Tell me, have I been sitting here all along? (answer) That sounds crazy!", "I'm watching myself right now being in a forest or something"*. When asked, residents generally reported the HMD to be comfortable as a wearable device (though slightly heavy), and found it pleasant as a display panel, though one participant expressed that she felt it uncomfortable when entering fast turns at high speed.

Body Language(s) was generally relaxed throughout the HMD experience. Most participants had passive and fixed postures during the *cB* trials, seemingly due to lack of physicality to move more freely. Most residents would on occasion spend time on orientation movements on various axes, to look around the VE.

Facial Expressions either neutral (with an occasional reaction to an event in the VE) or explicitly joyful (with a smile on their face and an impression of wonder, during the trial) (see Figure 9).

Exercise behavior such as biking speed seemed to relate to physical capacity, not from investment in the HMD experience. Most participants produced low forward moving speeds while a few were very fast. Fast participants were affected more in (thus faster) turns. Some participants took breaks from the biking and used them to look around the VE. This seemed to give an opportunity to perceive and explore VE, and to reload mentally. Breaks appeared to facilitate a more in-depth impression of the VE content and allow the participants to have longer sessions.

IVR/SC behavior observations often overlapped or combined the already described categories. Events in the VE would trigger reactions with participants to a varying individual degree but seemed to either correlate with the general enthusiasm or interest of the *cB* experience, or to the perceived impact of the VE event as experienced through the HMD. Participant 9, who was indifferent with the addition of *cB*, would for instance still react by moving her head backward in a sharp turn at high speed. With more enthusiastic participants, personal interest in the experience seemed to encourage enhanced orientation activity. Not all (data wise) interested participants showed their enjoyment with high levels of active behavior, however, seemingly due to a lack of physical ability to orientate much. Another indication of the effects of the IVR technology occurred (with all participants) when removing the HMD, re- introducing them to the real world surroundings. In this situation, most participants were warm, even sweaty from the experience. All participants were clearly affected by the shift in "reality", and needed a few seconds to realize and acclimatize to the transition.

V. DISCUSSION

These results gave several indications that are interesting to discuss concerning the hypotheses posed in of this paper. However, critical to note, is how results from SUS and IMI should be seen as purely suggestive to the effects investigated. Transforming a questionnaire into an interview approach, introducing an interpersonal interpretation into an initially quantitative data acquisition process presents various issues. Despite careful handling of the implications, a researcher being a part of the determination of participant responses brings underlying risks of misinterpretation or bias. Looking at the results, participant responses to the quantitative items, especially from SUS, show tendencies to of being slightly binary (extreme 'yes' or 'no' responses). This could be an indication of introduced bias. SUS item ratings for cB indicated a high level of presence with cB, where 8 of 9 residents gave r=2 out of n=3, but these results fit very well with the IVR verbal responses and behavior of the recorded video footage. Both qualitative comments and participant behavior during sessions clearly show the effect of the Oculus DK2 on participants' sense of presence, following their expanded possibilities to include SCs in their VE experience.

Figure 9. A participant stopping the pedaling, to enjoy a moment, orientating herself

This seems to be clearly the case concerning Slater's definition of the place illusion, from participants' comments on how they can see more and new objects in an otherwise familiar VE (see Figure 9), and feel as if they move through the spatial surroundings.

Interesting were also the reaction many participants had when taking off the Oculus at the end of the session. In these instances, almost all participants were warm or sweating from the intense experience, and it was clear that most participants had to adjust themselves to be suddenly "transported" back to the nursing home facilities. Concerning the degree of occurring plausibility illusions, this is a bit harder to evaluate from the procedure used in this study. On a few occasions, however, participants would react to branches passing close to their position in the VE and respond by moving away from it. This indicates a combination of a) a sensation of the place illusion of being in front of the branch, as well as b) the plausibility that the event of the branch hitting the user is in fact occurring. Other examples are how the birds made an impression on participants, or how some showed reactions to surface changes while moving through the VE. Meanwhile, these examples are not strong, as the birds were only very rarely situated in close proximity of the user, and the reaction to the surface changes (bumps, etc.) is not necessarily "an event" happening, depending on the perspective of the individual. Together, the results indicate a definite sensation of presence inside the VE for participants. In comparison, the less immersive cA did not receive ratings to suggest a similar presence impact.

SUS results and qualitative data thereby supported the theoretical expectation that increasing the immersive properties of the VE augmentation would increase the sense of presence inside the VE. Following this result, the hypothesis was that this would consequently lead to an increased intrinsic motivation towards the exercise activity, which would be shown from increases in the results from the IMI factor of Interest/Enjoyment, and subsequently in a predominant preference towards cB. This fits the general direction of the said hypothesis. Meanwhile, the clarity of this connection can be debated. For instance, the IMI results for cA were not as high as in another study evaluating the same condition [10]. Even cB scored slightly lower than the score for cA in this previous study. The reasons can be found in the particular participant sample, in addition to the sensitivity of having a smaller sample size. Overall, however, the IMI scores in this study were positive for both conditions, and convincingly so for cB. The previously conducted study could be seen simply to show supporting credentials of a potentially high degree of intrinsic motivation for this augmentation type in general, but further studies would be necessary to provide even clearer directions.

About the reported preferences of condition between cA and cB, only 5 of 9 participants preferred cB. This may seem slightly surprising, considering the qualitative user responses and observations, which were predominantly positive. Responses for almost all participants had numerous signs that cB was, hypothetically, improving their exercise experience with the augmentation, following the increased sense of presence, and the inherent enjoyment of the responses themselves. For the residents who chose cB, the improved experience was typically supported by responses like "*This is what I've been wanting all along*". However, to make the following statements "*This was really an experience, haha!", "It had a lot of hills, and it was almost ...you completely get the sensation what you were actually driving inside the landscape*", "*But it is amazing, to be frank, that this is possible, haha!*" "*When you look around, you forget that you are exercising. You just follow what is going on*", and still choose cA is curious. 5 of 9 is indeed a slight majority, but reasons for preferring cA are interesting, and might be found elsewhere than the sense of presence. Granted, the reported IMI levels could be higher for this specific user sample in general, but averages did favor cB.

Reasons could instead be found in relation to the Oculus DK2 itself, as a wearable technology for this user group, in combination with the method/angling the preference question. Participants were not asked if they would want use the Oculus DK2 again, or if they would use if most of the time, but to choose one condition for the future as if there would then be no other available.

From this study, a HMD such as the Oculus DK2 is not yet ideal as a technology for this specific elderly audience, from a series of perspectives. Experiences with the Oculus DK2 HMD throughout this study suggested the following. a) It is intrusive (placed directly on the body of the user). b) It needs careful wearing adjustment to be comfortable and sit correctly, and residents with limited motor skills were unable to adjust the headbands themselves or place the HMD accurately on their face. c) It needs perfect alignment with the eyes to produce a clear and undistorted image (which is difficult for an assisting bystander to determine). d) It demands to carry extra weight on the body - specifically the neck (which was a clear issue for some participants). e) The optimal use of an HMD regarding orientation requires the user to move his/her head comfortably on all axes, which was just impossible for some participants. f) For manuped exercise purposes, an HMD such as the Oculus DK2 requires its cabinet's volume in free space in front of it, which in one instance almost became a real issue, as some residents unknowingly only just missed the HMD cabinet for each hand-pedal cycle. With the lack of visual awareness of what is in front of the user (such as the manuped) while in the virtual domain, such situations can become a safety issue. This last argument removes one of the strengths of the manuped as an exercise device, which is the ability for users to exercise in an entirely unassisted fashion. Participants who reported a preference to cA never explicitly stated any of these reasons as the foundation of their choice. But by the observations from the sessions, the preference towards cA could be interpreted as an unconscious insecurity concerning the issues presented above.

Moreover, the novelty of the experience and the overall psychophysical intensity of the actual HMD experience should not be disregarded. As positive as a sense of presence might be (and showed to be), a sudden shift in the sense of presence between real and virtual domain, recognizing of the perceptual existence of "both" places at once, might be something to which this user group needs to adjust. The unfortunate example of participant 2, is another example of how the sense of presence effects is not necessarily, exclusively a positive addition. For months, before this study, cA was tested with residents where similar situations occurred - but never with a strong reaction from the resident sitting in front of the Samsung LCD. Technology such as an HMD would probably need to be gradually allowed to grow with residents, to gain higher degrees of preference. It would enable them to gain progressive experience with its characteristics, and to become better at avoiding substantial negative repercussions. The results from this study, therefore, points to that a physical therapy clinic for nursing home residents, using a similar augmentation type, should have a baseline, non-intrusive, conventional display type, such as the Samsung LCD. However, from the qualitative results in this study, is should be considered to offer an immersive HMD display as well. Increasing presence with growing immersive properties seems to provide unique and engaging experiences

VI. CONCLUSION

The main aim of the paper was to see if increasing immersive properties of a VE display by an HMD would increase the sense of presence, and in turn, increase the intrinsic motivation to exercise for nursing home residents, concerning a manuped exercise augmentation with recreational VEs. Results show that increasing immersive properties did, in fact, increase the sense of presence, and the intrinsic motivation, though to a smaller extent. Results also suggest that the HMD technology might still be slightly immature for this particular audience, primarily due to its size and weight, and that the strengths of increasing the sense of presence also comes with some problems in relation to overwhelming perceptual loads. This indicates that a certain amount of training and assistance seems currently necessary if elderly users such as nursing home residents are to gain the benefits of the experiences an HMD can produce.

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CHAPTER 13. PAPER VI. DESIGNING RECREATIONAL VIRTUAL ENVIRONMENTS FOR OLDER ADULT NURSING HOME RESIDENTS – HOW NATURE AND CONTENT MATTER FOR IMPROVING AUGMENTED EXERCISE EXPERIENCES

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ABSTRACT

With increasing age, muscle strength decreases excessively rapidly if physical activity is not maintained. However, physical activity is increasingly difficult with age, due to balance, strength or coordination difficulties, arthritis, etc. Moreover, many nursing home residents become unable to experience natural surroundings. Augmenting a conventional biking exercise with a recreational virtual environment (RVE) has shown to serve as an intrinsic motivation contributor to exercise for nursing home residents. RVEs might be able to provide some of the health benefits that regular nature experiences do, but more studies on content and design of proper custom designs for RVEs is necessary. This paper reviews the background for RVE design, describes four custom RVE designs for recreational VE exploration and presents user preferences among nursing home users concerning content and other pivotal design considerations.

CCS Concepts • Human-centered computing, Human computer interaction (HCI), Interaction paradigms, Virtual reality.

Keywords - Older adults, Multimodal Interaction, Virtual Environments, Design Framework, Recreation, Rehabilitation, Virtual Reality, Exercise Motivation

1. INTRODUCTION

At nursing homes, most residents are limited in their independence of everyday living, by varying degrees of cognitive or physical deficiencies. Physical conditioning can counteract these shortcomings, by rebuilding muscle mass, preventing sarcopenia (loss of skeletal muscle mass following high age), with cognitive and other more general health related benefits [1] [2]. Deceleration of physical ability increases with age and affects health and everyday life quality [3]. Meanwhile, many nursing home residents never engage in the rehabilitation offered in-house at nursing home physical therapy clinics [4]. Without a regular exercise routine, everyday tasks as getting dressed or eating independently will no longer be possible for many residents. Studies have highlighted numerous benefits of exposure to nature, from a psychological and physical level, being a motivation factor for physical activity and an activity choice for wellbeing [5] [6] [7] [8] [9] [10] [11] [12]. Virtual Environments (VEs) can connect real world actions and virtual world reactions, comparable to real world situations. VEs are used for balance and stroke rehabilitation [13] [14] and represent a novel, mature technology for facilitating nature experiences and recreational exposure benefits [6]. This paper is the most recent in a series of investigations into augmenting exercise, by a bike-oriented, indoor exercise routine, displaying nature-oriented VEs for older adult nursing home users to increase motivation towards regular exercise [15] [16] [17] [18]. The goal of the paper is to evaluate what constitutes the dominant parts of the recreational experience, based on four recreational VEs (RVEs) designed to achieve recreational effects in the virtual domain, and to suggest how to design for a recreational impact on the user experience.

2. BACKGROUND

In a recent series of studies at Akaciegården nursing home (Denmark) [4] [17] [18], unusual effects on the exercise have indicated usefulness for multimodal VEs to augment a bike- reminiscent exercise. The VE augmentation was designed as an additional layer to of a manuped exercise, maintaining the exercise routine fundamentals but adding the user experience of a recreational ride along a fixed trail in a nature-based RVE. The interaction design was kept to the usual pedaling, to accommodate physical (e.g. motor skills, strength, agility) and cognitive (e.g. reaction time, coordination, conceptualization) limitations of the majority of the user group – a necessary precaution taken from pre-testing. From the augmentation, users would see the RVE on a visual display (e.g. a 46’ LCD TV) and hear a corresponding simulated soundscape (e.g. sounds associated to the environment) of the RVE content in a stereo display (e.g. through speakers). When pedaling, the virtual camera moves forward into the RVE along the trail, suggesting the user driving forward along a fixed path. The pilot study [4] used a small and straightforward RVE. Results indicated that the users connected the exercise actions, the behavior of the RVE, enjoyed the possibility to travel to another place and to explore its content. The RVE was described as beautiful, and users felt as if being part of its nature setting while exercising. The majority of residents wanted to continue using the augmentation and expected it would increase their exercise frequency. Residents also suggested improvements for future implementations, such as diversity, multiple (different) RVEs, more content to explore, and contextually fitting content [4]. In a review paper by [16] Bruun-Pedersen et al., current practices for designing custom RVEs (as opposed to real world replications) were investigated to aid RVE developers without landscape architect oriented backgrounds. Sparse literature forced a combination of fields: realism in real world environment replication in VR [10] [19] [20] [21], tourism and recreational experience design [6] [20] [22], urban design and urban planning in VE [23] [24] and spatial recognition for navigation in VEs [25]. Findings condensed design considerations into *RVE content* and *RVE features*, with VE *landmarks* to spatially structure content placement in the RVE [16]. Four RVEs were built and used subsequently in two studies measuring the effects of the augmentation on exercise motivation with nursing homes residents [17] [18]. One study tested exercise motivation on 4 months longitudinal basis, using the Intrinsic Motivation Inventory (IMI) as the instrument. User responses showed an increase in motivation, due to the enjoyment of experiencing and exploring the RVE while exercising [17]. In a later study [18], intrinsic motivation was investigated when increasing the immersive system properties (as defined by Slater [26]) of the augmentation with an Oculus Rift DK2. Results showed a high increase in the sense of presence, but only a slight increase in intrinsic motivation. Qualitative responses suggested that increased sense of presence also greater awareness on the RVE, with VE scenery and content becoming unusually apparent and impactful [18]. A slight majority of residents preferred the experience through the Oculus Rift DK2. But the technology also showed to be unsafe for residents to use unassisted, as they would lose orientation in the real world environment to the degree, where assistance was for a few participants, to avoid them not hurting themselves on the hand-based pedals on the manuped.

2.1 Nature Experiences Matter

Deprivation of nursing home residents' independent travel outside the nursing home is unfortunate and disables residents the experience of real nature-based environments. According to Irvine, et al., park visitors in Sheffield, UK (n=312) consider park visits a resource for health and wellbeing, to perform physical activity (e.g. walking) and enjoy the green space qualities (nature and park features). While in-situ, visitors describe the effects of the park experience physically beneficial, by relaxation and revitalization, along with positive affective effects [5].

Studies on nature exposure show how it produces relaxation, induces positive mood, recovers attention capacity and cognitive functions, reduces stress, increases self-discipline, and clears various types of 'mental noise' (such as rumination, which prohibits effective mental functioning) [6] [7] [8] [9] [27]. The term *restorative* is used in identical fashion as *recreational*, the trend being the former used predominantly in medical or physiological relations [7] [9] [10], and the latter referring primarily to leisure activities, nature environments or tourism [22] [28]. This paper will use the term *recreational* when referring to augmentation VEs, due to the leisure-oriented user experience they are designed to induce, and *restorative* when discussing the psychological effects as found in the literature.

2.2 Restorative Environment Components

According to Kaplan [7], the restorative aspects of (non-VE) nature settings can be understood from the perspective of *attention*, as a deceptively finite mental resource that needs periodical 'resting' from demanding influences of an environment. Kaplan proposes certain types of natural environments to be restorative for attention resources if inherently delivering an experience based on four components.

1) *Being away;* removing an individual's attention from the concerns related to one's everyday living environments. 2) *The extent;* restorative environment must contain rich and coherent stimuli, which in combination induces the sensation of a 'whole other world' that "*must provide enough to see, experience, and think about so that it takes up a substantial portion of the available room in one's head"* [7]. 3) *Fascination;* which for nature settings is predominantly a 'soft' fascination, as opposed to 'hard' fascination from adrenaline producing experiences. It is obtained through content or settings that do not require *directed* attention (requiring effort and focus), allow appreciation of environment features, and open possibility for thought and reflection. 4) *Compatibility;* an individual's purposes must fit the environment characteristics, and the environment must provide the information needed to meet the individual's purposes. 'Incompatible' situations require focused attention on problem solving [7].

Kaplan highlights that the conceptual notion of *being away* is essential, to be understood as 'attention displacement' rather than physical transportation. An environment's *extent* refers to richness, coherence and complexity, more than size. Small areas can have sufficient stimulating capacity (Kaplan highlights a Japanese garden), if succeeding the observer to 'connect' and effortlessly explore its content [7]. Kaplan's descriptions infer that the inherent substance of *extent* is linked to induce *fascination*, but as coherent 'whole' world, not a stream of eclectic instances of fascinating content. Natural settings based *fascination* comes from aesthetically pleasing picturesque nature objects or 'soothing' events which are effortless to attend, leaving an opportunity to think beyond the event itself. Kaplan suggests examples of soft fascination entities as clouds, sunsets, snow patterns, the motion of leaves in the wind, and wildlife [7].

2.3 Mediated Nature Experiences

Restorative effects with natural environment stimuli have been shown by just 5 minutes through a glass window [11]. Studies on restorative effects of technological mediation of real world recreational environments show mixed results [12] [11]. Meanwhile, Depledge, et al. suggest a "*resurrection of interest in the design and study of high-fidelity, ambience-rich virtual environments* " [6], to allow disabled or elderly individuals to have convincing nature experiences in VR, by the evolution of contemporary VE and virtual reality (VR) hardware and software, which finally seems ready and affordable [6]. VEs in rehabilitation studies mainly serve a casual ambiance role for a primary task [29] [30] [31]. Many studies that use VEs designs for central parts of their work [13] [19] [32] [33] [34], omit comprehensive findings on the role of VE or RVE content design specifics. A study by Wargnier, et al. [35] on post-fall syndrome rehabilitation with older adults, used high-fidelity VEs as context, which showed aesthetics and context specifics of VEs as an important motivational factor for older adult users [35]. An indoor corridor VE was rejected by older adult users, being too 'narrow', and an outdoor city based VE for being 'cold/unwelcoming'. Two nature-based VEs (forest and park) were described as satisfying and realistic [35]. Wargnier, et al. did not present the causality of the user responses. Depledge, et al. declare it an issue for RVE development, how the body of work is minimal on the cues and clues that trigger human interest and sense of wellbeing in nature environments (real or virtual) [6].

2.4 Recreational Design Considerations

The review paper by Bruun-Pedersen, et al. [16] proposed that RVE designs could be comprised by considerations of *RVE content* and *RVE features*, structured according to an *RVE spatial structure* (inspired by Vinson's notions of VE navigation guidelines [25]). In the following, those considerations will be shortly outlined, with additional mapping tools from architectural game space techniques, and RVE design considerations by Kaplan's four components to restorative environments.

2.4.1 RVE Restorative Components

Kaplan's conception of the four components for restorative environments offers perspective and understanding of restorative RVE user experiences. From a design/development perspective, directive towards effortless attention through 'soft', rich and coherent experiences of *extent* and *fascination*, should be used to guide the overall design and expression of the RVE from a user experience viewpoint. It complements the previous review's confinement to RVE *content*, *features* and *spatial structures* [16]. From a practical development perspective, the attention displacement of *being away* is similar (but not identical) to the mind's sensation of transfer to another place, resembling the mission for VR since its inception, by considerations of e.g. presence and immersion. The 'sense of presence', as described by Slater [26] is comprised by the perceptual illusions in VR of *place* (the sensation of 'being there' in the VR environment) and *plausibility* (the sensation that events are apparently happening in the VR environment do happen). The immersive properties of a VR system are evaluated by the system's use of multimodal displays and tracking of user actions. Presence sensation and the immersive properties of a system are fundamental considerations for VE designs and supports (while not guaranteeing) the RVE experience to deliver on Kaplan's *being away* component. *Extent* lends its concerns towards the comprehensiveness and intricacy of the RVE content while remaining coherent to keep a classification as restorative. Nature settings can positively be large and obtain *extent*, but small areas can be similarly restorative, if following the rules [7]. As previously suggested, aesthetic directions of an environment's *extent* seem to be linked to its facilitation of *fascination*, but Kaplan provides no more examples than is already described. It is up to RVE designers to introduce additional examples to the library of soft fascinations. The importance of *compatibility* showed in the pilot study, by participants responding to a perceived incoherence of *extent* elements in the study's RVE. A sequence of buildings was perceived contextually unfit, which degraded the user experience for the participant, to a degree where the RVE had no interest to the participant. This indicates the importance of Kaplans components, and how older adults' relationship with technology in general should not be neglected. Ijsselsteijn, et al. [36] describe the older adult user group as proponent of technology, under the requirement that they understand and appreciate its purpose. The pilot study suggested *compatibility,* as participants felt an intuitive connection between exercise actions and system feedback [4].

2.4.2 RVE Content Considerations

Positive user responses in [4] related heavily to nature content. Trees, water, houses, and nature elements figured with rhetoric indicating *fascination*. Residents also expressed (RVE) needs; increased content density and content diversity, additional and larger scale RVEs, dynamic and 'lively' events, and higher density of distinctive objects to fuel the exploration desire (compared to the simple pilot study RVE), which interestingly supports the restorative component of *extent*. Depledge, et al. state that RVE content is critical, and highlight *water* as particularly important inclusion for restoration. Strong considerations are also *forests visuals*, *outdoors environmental sounds* (birds, water and wind), *natural colors* (greens, blues, and browns), and *air* movement. The presence of other visitors might ruin the restorative effect [6] [22]. This fits with Kaplan, as a potential director of attention and problem solving.

In a visitor behavior study, Dorwart, et al. [22] examine perceptions and preferences of nature experiences for visitors at the Great Smoky Mountains National Park trail tour. Results report how "*Whether hiking alone or with a group, each of the 33 participants noticed and photographed more nature-oriented details such as plants and wildlife than any other type of feature*" [22]. Subsequently themed *nature-oriented details,* this appreciation of small, detailed content in close proximity to the trail were found to be most important aspects of a *recreational* experience. The content examples are similar to those of Depledge, et al. [6] and the aforementioned pilot study results [4]. Plants, 'a green carpets of vegetation', wildlife, vast and surrounding forest, rock formations, and combinations of such natural elements for close inspection were highlighted to inspire exploration [22]. *Scenic values* were the second most popular theme [22], represented by broad views and distant locations overview, high altitude vistas of trees and beautiful scenery, light and shade combinations, and 'natural elements' such as waterways and waterfalls – the last of which Kaplan also highlight as restorative [7]. The *management influences* theme was man-made objects by/on the trail (stairs, shelters, and other constructed elements) as positive contributions or facilitators to the experience, but required to blend into the environment. *Depreciative behavior*; a negative predictor to e.g. litter, trash, general destruction of natural content or lack of maintenance [22]. Lastly, the trail itself needs visual compatibility to its surroundings, while having distinguishable textures. It should curve if attention is to be placed on respectively the trail itself and nearby contents.

2.4.3 RVE Feature Considerations

RVE Features in the context of previously mentioned RVE design recommendations is an umbrella category, covering both technical and artistic considerations serving to enhance restorative features of the RVE representation and build. Complete photorealistic rendering would objectively be optimal conditions to induce an ecological experience of a nature-oriented RVE, but it would require unrealistic contemporary computational demands. Some aspects of realism prevail others, as Kort and Ijsselsteijn [10] state that multimodal VEs do not need photorealism to achieve convincing perception of realism. Lange [24] suggests that correct imagery and geometric detail are not implicitly required to achieve a perceptual impression of realism, but the *behavior* of the VE *must* be reasonable to the user. Hall suggests that *high image complexity*, *subtle shading* and *rich surface detail* are central for the perception of realism [21]. Kort and Ijsselsteijn [10] argue that the perception of a real world environment in VR is enforced by environment object details as *high quality textures*, *correct scaling of objects*, and *realistic lighting*. *RVE feature* considerations thereby relate to technical aspects of the RVE and its content (environment behavior, rich surface details, high resolution textures) and 'artistic' design choices (scale, lighting, shading, complexity) to achieve important effects for perceived 'recreational realism' by how features combine with content.

Towards the ‘ecological’, a balance between features must be decided, between what is technically possible, and what should be rationally necessary compared to required hardware performance. High image complexity, realistic lighting, subtle shading or refraction behavior of water are examples of demanding technical *feature* aspects. Inspiration from media can aid the identification of which characteristics that should be considered central for the best perceived realism/performance output for given RVE location [24].

2.4.4 VE Spatial Structure

Efficient navigation of any environment is achieved through an understanding of the area, by recognition of its individual characteristics. Vinson [25] proposes *VE navigation guidelines* from a *landmark* typeset, of unique reference points, making area identification easier. Increasing recognition ‘potential’ could aid dementia-burdened nursing home residents to remember locations the RVE. The recollection of positive experiences with the RVE exercise is inherently valuable, as residents’ motivation to return to the RVE exercise is logically dependent on their ability to remember it. Landmark types serve individual purposes. *Paths* (such as streets, canals) are channels for movement, *edges* (fences, rivers, etc.) highlight boundaries, *districts* (neighborhoods) are distinct areas formed by boundaries, *nodes* (town square, public buildings, etc.) are focal points for travel, and *landmarks* (such as statues) are distinct and impenetrable objects [25]. Individual landmarks need detail variations such as height, shape, etc. to make them distinguishable [25]. Vinson recommends landmarks to be man-made objects, as they are reportedly easily remembered, compared to nature-based landmarks. Nature-based content is to be considered *virtual objects,* which represent most of the VEs identity and ‘fullness’ without being remarkable as landmarks. Vinson proposes nature oriented landmark types to be man-made items (*roads, sheds* or *fences*), land contours (*hills, slopes* or *cliff faces*) or water features (*lakes, streams* or *rivers*) [25]. Vinson’s preference towards man-made landmarks as the dominantly recognizable object type in RVEs will be challenged by the RVE designs later in this paper.

2.4.4.1 RVE Design Using Landmarks and Spaces

The landmark typeset aid an RVE design by top-down macro- or bottom-up micro processes. Top-down mapping is useful keep organization to place landmarks evenly throughout an RVE and ensure proximity to typical user placements. Vinson only touches upon this, but useful terminology is offered within architectural approaches to game level design [37]. Spatial features and relations vary e.g. regarding *layout types*, such as labyrinths (one path), mazes (‘branching’ labyrinths) or rhizomes (all points connect), and *spatial/confinements sizes* (narrow to intimate to prospect spaces). Spaces and events in an RVE can be mapped through top-down *diagrams* (maps) of layout and spatial dimensions, for example in a *molecular* diagram. Totton [37] recommend a similar landmark typeset as used by Vinson [25]. Top-down diagrams can be anything from simple mock-ups of space/path relationships, to very detailed mappings of landmarks, paths, edges, nodes, districts, etc. [37]. A diagram example used for four RVEs is presented in Figure 5 Karjalainen, et al. [33] highlight how moving through a landscape and viewing it from many different angles can change the perception of the landscape drastically. A top-down mapping must be combined with the bottom-up, micro perspective of an active user's experience. Placement considerations of central content must then be performed in all possible viewing angles of a user, which increase dramatically when using head tracking enabled setups, such as a HMD. The inherent movement limitations of a trail-based RVE design allows accurate predictions on what contents a user will be allowed to see at any given trail-position, which makes the evaluation easy to control, regarding individual landmark types and their roles in a particular context.

The micro (user) perspective is also imperative for evaluating the effects of *RVE features* for perceived realism (e.g. lightning), and picturesque sights, scenic values of a particular area, etc. These must be convincing from a restorative perspective (*extent, fascination, RVE features*), but uphold hardware performance requirements. A nature landmark as a water stream experienced in proximity to the user position welcomes high image complexity, rich surface details and high quality textures. If it is never in proximity to the user, these features can be downscaled and only receive a bit of lightning and movement to cover with general but coherent RVE behavior. Such decisions should be possible to foresee from a top-down diagram, with the effect being tested eventually from the micro perspective.

3. RVE IMPLEMENTATIONS

The design considerations comprised in previous sections recommend Kaplan's four components to orchestrate the general direction of the experience from the 'underlying' courses of *RVE content, RVE features* and *RVE spatial structure*. As previously described four RVEs were implemented following the pilot study. The RVE's identities were based on user responses from the pilot study [4], availability of 3D assets for the chosen game engine platform (Unity 4 Pro) appropriate to support a recreational experience, from restorative aspects found in literature. The RVEs will from now be considered *districts*, following the landmark typeset. The four district identities became Lake Park (akin to NY Central Park), Mountain Top, Winter Forest and Country Side (a revision of the pilot study VE).

3.1 Overall Design Considerations

Attention displacement, related to *being away*, was already suggested to exist in the augmentation user experience from responses of the pilot study: "*the sudden* *ability to go outside and have the world moving towards you, in front of you, and the ability go places I've not gone before, seeing things I never knew. This is wonderful*" or "*Something always happens before your eyes and you feel that it is you are driving that trip yourself*" [4]. This was despite using a trivial RVE on a 46' LCD TV with a similarly trivial stereo soundscape. A similar effect could thereby be anticipated in the new designs and would later be evaluated, with varying immersive system properties [18]. A conscious effort was placed on the *extent* of each RVE design ensuring all RVE designs to be rich and individually coherent in content, content density and complexity (a predictor to facilitate exploration desire, according to Dorwart, et al. [22]). Kaplan is not particular about how to achieve *extent* or *fascination* components. So gauging their existence and practical implementation into the district designs was based partially on inspiration media documentation (as loose reference), availability of 3D assets in the Unity 4 Pro software, recreational/restorative environment content insights from literature and implementation of RVE features. Landmark and virtual object placement, and path grid design were developed in parallel for each district, aided by a central path diagram to frame the governing structure. To achieve *fascination* throughout the districts, all RVE designs were subject to an extensive development time and high iteration count of bottom-up user perspective trials, to obtain micro-perspective user experiences (including viewing angle accommodation for HMD-based exploration of locations), gauge the *extent* of content, and internally evaluate 'soft' *fascination*. Considerations of *extent* and *fascination* would vary between districts, based on their core identity, by virtual objects and landmarks in proximity to the paths. *Extent* was primarily executed by an overall sensation of richness and coherence of *nature-oriented details*, and *fascination* with overall 'soothing' experience, by a combination of proximity coherence, general landscape contours, aesthetic effects from lighting and shadow, and ambition to include *scenic values* to as many locations as possible. As the system would steer and choose a route for the user through all RVE paths, this contributed to limit directed attention and problem solving. In combination, this design orientation was created to inspire 'effortless attention' experiences that *leave a place for thought*, as Kaplan describes it [7].

3.2 The Four District Designs

As implied by their names, the four districts differ in virtual objects, landmarks, spaces, path types (path texture, its grid and its slopes, connection methods between spaces, etc) and overall district behavior. All district have inherent strengths and weaknesses by their restorative elements.

Lake Park (LP) (Figure 1) identity: a picturesque RVE experience that combines diverse vegetation with man-made objects, surrounded by skyscrapers to indicate an overall urban location, similar to New York's Central Park.

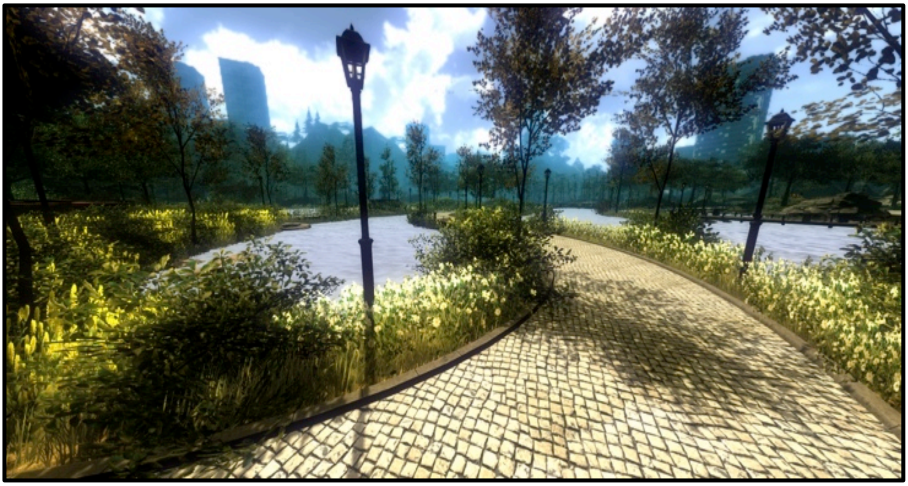

Figure 1 – Screenshot from Lake Park RVE

The path is a wide, brick stone based, leading many times across a large lake through a network of small bridges. The path has many curves, and many junctions to lead the user through the space in myriads of route combinations (see Figure 5). The *extent* of the district is built from diverse, close and far proximity content. Man-made (in these descriptions, short for *management influence*) virtual objects are romantic style benches, old style lanterns, decorated fences at roundabouts and bridges. Nature- based virtual objects are large quantities of varied, groomed nature based contents such as flowers, bushes, rocks, and trees. Man-made landmarks are fountains and nature-based landmarks are waterfalls (landmark), pigeons (life events) pigeon landing spots, local area types (pine tree area, waterfall area, central lake area, etc.). Scenic views are often available through lake overview. Soft fascination points are pigeon wildlife, the lake, tall nature objects as trees, the wind moving the vegetation, light/shadow casting and movement from tall objects (mainly trees). The soundscape of LP mimics the content, with diverse bird chants, and other sonic landmark representations such as waterfalls, to be noticed while traveling the path. Critique for LP is that it is flat, polite and lack the dynamic and diversity of e.g. Mountain Top.

Mountain Top (MT) (Figure 2) identity: a resident requested a mountain landscape during the pilot study and MT was designed to be driven with scenic values of the high altitude. The path only has eight junctions for alternative routes, resulting in long paths, which however varies with many slopes.

The gravel surface of the trail appears man-made opposite the rock faces. Other man-made landmarks are wooden fences, a cliff- based house high above the trail, an abandoned construction site, three massive stone bridges allowing the path to cross between cliffs and two abandoned bridges above trail level which cannot be reached.

Figure 2 – Screenshot from Mountain Top RVE

Nature landmarks are waterfalls, bird sites, sites for scenic extremes, characteristic areas such as caves, oasis, a lake, a water stream, huge cliffs towering high above, and deceptively dangerous path segments with seemingly no protection from falling. The *extent* comes more from scenic value based content richness, than proximity content richness, where MT is sparse. *Fascination* characteristics are wind, large-scale objects (distant or close), complex lighting and shadows from trees and expansive mountain facades, active sparrow and eagle wildlife, massive waterfalls, caves, lake, and water. Soundscape features are blowing winds, waterfalls, sparrows chipping and screams from the three eagles. MT might go against the four component restorative ‘prescription’ slightly, by its dramatic edge over the calming, and its focus on scope and scenic characteristics, over a large quantity of small nature-oriented details as virtual objects.

Country Side (Figure 3) (CS) identity: the pilot study RVE revised - a calm, undramatic and small district. A single, wide path gravel/dirt trail with no junctions circles a lake.

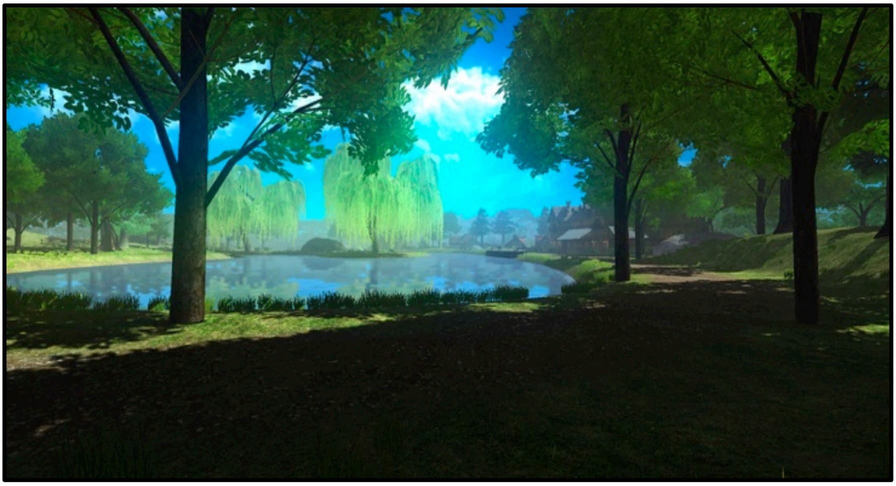

Figure 3 – Screenshot from Country Side RVE

In near path proximity, nature-oriented details such as trees, rocks, flowers and other vegetation are virtual objects and form the *extent*. A set of large Willows represents the large nature-based landmark, along with a flock of flying sparrow. Man-made landmarks are small and medium houses and a small bridge over the lake. *Fascination* comes from the overall nature scenery, the general overview of the lake, and all its content, the calmness, and the wildlife. Critique for CS is that it is small and one-sided.

Winter Forest (WF) (Figure 4) identity: designed to be a calm, quiet, intimate, beautiful, snow-based forest district, as well as a contrast to the rest of the districts. The path is frozen dirt, with junctions and many short but intense slopes. Man-made objects are represented on several occasions, mostly as wooden houses, large wooden fences, lamps, lanterns, and city brick walls, however, allowing path pass-through. Live torches are placed on many of these constructions. Virtual objects are pine trees and the cover of snow, dismissing other districts ground-based vegetation. ‘Snow formations’ is on Kaplan’s list of ‘soft’ fascinations, and further adding are snowflakes falling.

Figure 4 – Screenshot from Winter Forest RVE

Scenic values are limited by fog, many turns, and no large vistas. *Extent* in WF comes from complex scenery geometry, high quantity of trees, complex close approximation scenery, the complex scenery lighting following the many contours of the snow, and snowflakes. A fog and highly twisty trail limits vistas. *Fascination* comes from the already mentioned content and features (lighting, elaborate but calm scenery, etc.). Critique towards WF is its almost complete lack of green/plant based nature-oriented content, except for the pine trees and some rocks. The strength of WF's unique and meditative mood, is oppositely removing many possibilities for virtual object based content diversity, which could help make areas more unique.

Figure 5 provides a top-down diagram mapping of the four districts (similarly to what Totten refers to as a molecule diagram [37]), including path grid, space relations, and various landmark placements. Besides CS, all path layouts are mazes, with connections between main spaces, but not all link with each other (as if a rhizome). While path size is narrow to intimate, depending on the district.

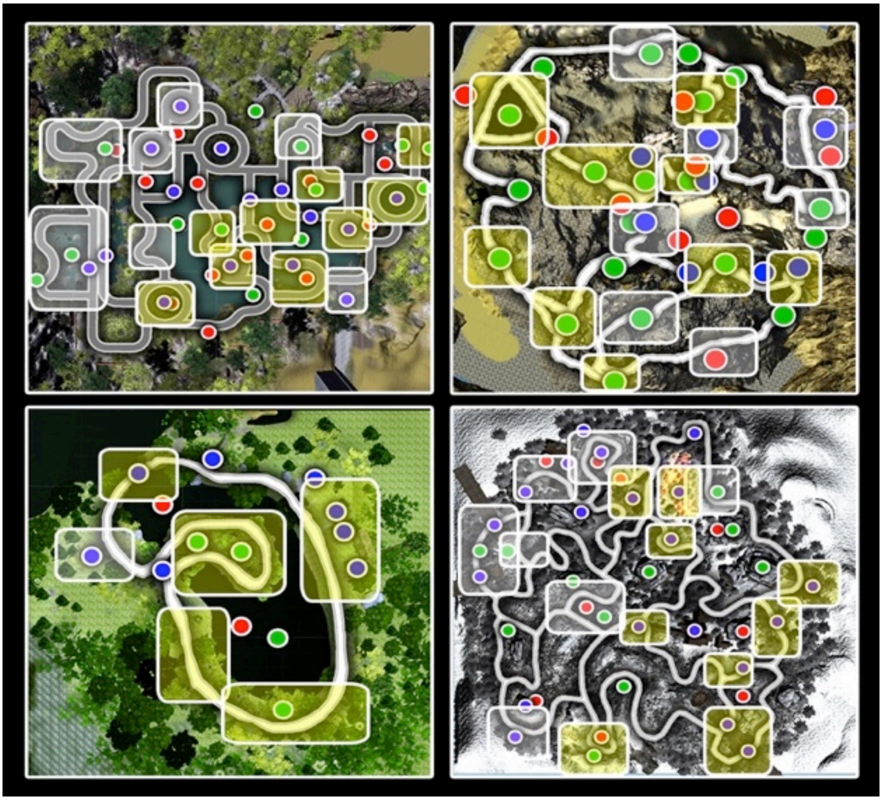

Figure 5 – Top-down overview of the four districts. From top-left to bottom right; Lake Park (LP), Mountain Top (MT), Country Side (CS), Winter Forest (WF). Yellow transparent squares are nodes used for survey interview 3 (see '4.2 Survey Interviews').

The landmark type *path* in the diagram is the path grid, while many *edges* (e.g. fences) are not represented in an obvious fashion in Figure 5. Dots indicate most prominent landmarks in each district. More are in the actual RVE. Blue dots are man-made landmarks, green are nature-based and red are instantiations of wildlife, such as various type birds. Transparent squares are considered nodes (colored squares to be explained in Methods section). For reference of scale, CS (bottom left) is four times smaller than the rest. The path system of the districts shows CS to have the simplest, with only one path and no junctions for alternative routes. The three larger districts (MT, WF, LP) have their spaces and nodes interconnected by junctions.

The path is a central part of these RVE designs. From the top-down diagram, the most simple path grid of the three large districts is MT, with long and relatively straight paths. The long, singular path travels give a steady horizon vista while traveling many areas, but MT paths have diversity through are not visible from the diagram, such as paths slopes, and passages through caves. All paths beside CS have individual characteristics. LP has almost twice the junctions of WF, but LP paths are completely flat, wide and turns are smooth. But the high quantity of junctions and turns means the horizon shifts often. WF has fewer intersections than LP, but a far more complicated path. While ascending and descending less than MT, WF paths regularly change altitude and direction (also outside junctions), which (along with falling snowflakes, and the occasional crow (bird) and torches) represents one of the few more 'lively' effects of WF.

From the user responses in [4], diversity, size, 'life', and contextual coherence of objects within each RVE as well as several RVEs to choose from, were requested additions to the pilot study's straightforward and small RVE. However, insights into more detailed user preferences from residents in [4] were not possible. The four RVE designs just described are believed to deliver on these suggestions, in different areas and with different methods between the individual RVEs. Which of the characteristics of the models will be addressed in the following parts of this paper.

4. METHODS

As explained in Backgrounds section, the RVE designs discussed in this paper have already been inserted and used by nursing home residents for more than 10 months before this study. From past research [4] [17] [18], user responses concerning the exercise augmentation were positive, but the design considerations presented in this paper have not yet been evaluated properly. More work is needed in this area, as described by Depledge, et al. [6], and the evaluation of the four RVEs in this paper is a small step in that direction. The first part of the design measures in this article is a review of user responses related to the design considerations described in this paper, recorded in two previously performed studies [17] [18], which will onwards be referred to as Study 1 (S2) and Study 2 (S2). The second part is a series of survey interviews performed directly for this paper, which will onwards be referred to as Study (S3). The overall goal in both parts is to isolate user preferences in respect to the just presented RVE designs (components, content, features, landmark relations, path design, etc.), and obtain insights on which aspects have made impressions on users during their experiences with the RVE augmentation.

4.1 Recoding data from Study 1 and Study 2

In two already mentioned studies, user responses were recorded concerning the RVE user experience. S1 focused on measuring changes in intrinsic exercise motivation over a four months period [17]. S2 focused on the effect on intrinsic motivation as a consequence of changes to the sense of presence from increasing immersive system properties [18]. While the premise, methods, participant group and visual display technology was different between S1 and S2, both procedures included the same RVEs, and both included the possibility for qualitative, open-ended responses concerning the user experience of the RVEs. As part of the original S1 measure, participants were asked to comment on the positive aspects of the augmented exercise. The system setup for this study was using a 46’ LCD TV for the visual display. As part of the original measure in S2, participants were video recorded, and behavior, as well as comments on participants' initiative, were subsequently transcribed and coded. The system setup for this study was using an Oculus Rift DK2 as the visual display. As data for RVE design in relation this paper, responses from S1 and S2 were coded following the RVE design considerations previously described. Coded responses from S1 can be seen in Table 1, and coded responses from the recorded footage in S2 can be seen in Table 2.

4.2 Survey Interviews from Study 3

In the survey interviews, a questionnaire was read out loud to participants in S3. Items were all formally written as for a conventional questionnaire for written responses, by a combination of open-ended questions or check boxes. However, items were read out loud in interview form, with items responses written down by the interviewer. This method was based on physical limitations of participants prohibiting many to control a pen accurately. Three rounds of survey interviews were performed with residents at Akaciegården (n = 10, average age: 85.7 ± 9.8).

The first survey interview (S3.1) had five items, plus follow-up, open-ended elaboration for each item. The goal was gaining general insights to preferences of district (why?), the believability of behavior (how?), hints possible restorative effect of the experience. For instance if it was important to residents, that VEs were nature-based (and why?). If the RVE provided a sense of relaxation (a restorative indication), and if it had been an upset for a participant, if the RVE augmentation had been unavailable. All items encouraged additional, open-ended comments.

The second survey interview (S3.2) had 20 items, with the goal of gaining more, but still general insights concerning the preferences and perceived importance on the user experience of different landmark approaches, extent orientations, fascination aspects, and path design. Each two items (1-2, 3-4, etc.) would be presented in pairs, each illustrated with a printed image from a location in one of the four districts, representing an example of a choice. The interviewer would pose a question into an overall tendency, for example, the user’s perception of importance for the exercise augmentation experience of nature-based objects as opposed to (or including) man-made objects. To this question, the user could chose one or both to be important. Despite presented in a fashion similar to a multiple-choice design where only one option can be selected, participants were encouraged to choose both options if perceived to be of similar importance.

The goal of the third survey interview (S3.3) provided insights into RVE content preferences and impact. The procedure asked each participant to relate to 33 presented images (the locations outlined in Figure 5 by a transparent yellow square), from respectively nine sites in LP, five from CS (due to its smaller size), ten from MT and nine from WF.

For each image, participants were asked to choose one of the following response categories, for each image:

1. *Consciously remembering having been to the specific location before, while exercising (based on what content?).*

2. *Not remembering the specific location, but recognizing specific objects at the location on the image (which objects?).*

3. *Not remembering the specific location, or any content represented in the image.*

From the logic of having to be able to remember a thing, to relate a thing, and by qualifying and quantifying which landmark types, spaces or smaller content details can be considered memorable, this should indicate which content types should be considered a priority for future RVE designs. The landmark typeset is meant to increase recognition, which could help the variously demented residents remember their RVE experiences. The procedure also included the possibility for additional comments relating to personal preferences.

The response categories were later quantified, and open- ended details to the content of the image coded for content recognition or further qualitative comments.

5. RESULTS

Common for results in respectively S1, S2 and S3 was obtain insights on RVE related experiences with the RVE augmentation. While not the main criterion of original studies, user response data from S1 and S2 did contain open-ended, qualitative user responses, fitting to what Depledge, et al. [6] refer to as ‘clues and cues’ to a restorative environment experience.

5.1 RVE Coding of previous user responses

S1 searched for answers to the research question of whether the RVE augmentation of the manuped exercise would increase motivation compared to the conventional exercise, measured after a longitudinal exposure of 4 months. Categories *Extent* and *RVE Content* overlap, as they both refer to content. No responses fit *RVE features* and *RVE spatial structure*, hence their lack of appearance in Table 1.

Table 1: S1 Verbal Participant Responses

Being away	*It's like being in nature.*
Extent	*You want to see what is around the next corner. * I like to search for the squirrel. * There is a lot to look at. Turning around corners and seeing beautiful things creates expectations in me. There is always something new.*
Fascination	*I'm accompanied by images. It is lovely and diverse. Beautiful. * Lovely tours. * It is lovely to watch. * All the landscapes are good. * It's pretty, all of it. I like the change of seasons (between environments). * Time goes fast, while its all flowing by. * It makes me think about ski vacation. Something I would like to be able to try.*
Compatibility	*Amazing. You see and experience something while you bike. You use more senses than if simply looking into a wall. * There is something new all the time, and I always end up going 1 or 2 kilometers more. * You speed up. Especially going up and downhill. You have to struggle up hill, but want to keep up downhill. You follow the trip as it is. There is more to ride for. * I switch environments a lot. * Time goes faster. * You keep going for longer*
RVE Conten	*The mountain is amazing. * Snow and mountains are really good. * I like the Waterfalls. * I really like the weeds!*

S2 researched the effect on motivation, based on the sense of presence when increasing immersive properties to the conventional exercise. The category of *Extent* and *RVE Content* overlap, as they both refer to content. No responses for *RVE spatial structure* were found, relating to Table 2.

Table 2: S2 Verbal Participant Responses

Being away	*It seems very real * I mean, it's so natural * I feel that I'm driving around in here, I've never tried that before * It feels like I'm really about to go down hill! * You completely get the sensation what you were actually driving inside the landscape. You are out in the middle of it all! Can you believe it? * Tell me, have I been sitting here all along? (answer) That sounds crazy * But just the life that is around you, compared to the other (condition) I think. You almost feel that you need to move your leg (not to hit a plant or branch)*
Extent	*There is so much to watch here!*
Fascination	*Wow, we can quickly agree that this is very pretty", "It's peaceful"*
Compatibility	*This is what I've been wanting all along. When you look around, you forget that you are exercising. You just follow what is going on*
RVE Content	*There are the birds again * It's amazing to look at the birds * I'm watching myself right now being in a forest or something*
RVE Features	*Is that the real sun that you can see?*

5.2 Survey Interview Results

Quantitative responses from survey interview 3 (S3.1) can be seen in Figure 6. There are no clear preferences of district between participants, but clear indications that participants generally accepted the behavior of the RVEs to be realistic. All participants appreciated the nature orientation of the augmentation, and a majority believed it to induce relaxation (indicating restorative characteristics). The one participant denying relaxation was, however, positive about the experience, from excitement (MT).

Open-ended qualitative responses to the items in Figure 6, showed preferences for MT by *fascination* aspects, such beauty and impressive perceptions of both vistas and near-path nature content, trees, 'happenings' (presumably objects such as waterfalls or birds) and open spaces. For WF, the calm mood of the district, its 'life' (snowflakes), as well as a perception of near real-life believability (realism) was appreciated. Responses to nature included "*I love nature. Nature freshens the soul. Completely. I am not used to this enclosed lifestyle*", "*The Park has so many facets to it, and you see the park from so many angles. So you get a lot of different impressions*", " *or "Everything nature. The mountain creates expectations, concerning what's around the next corner. But I like them all"*.

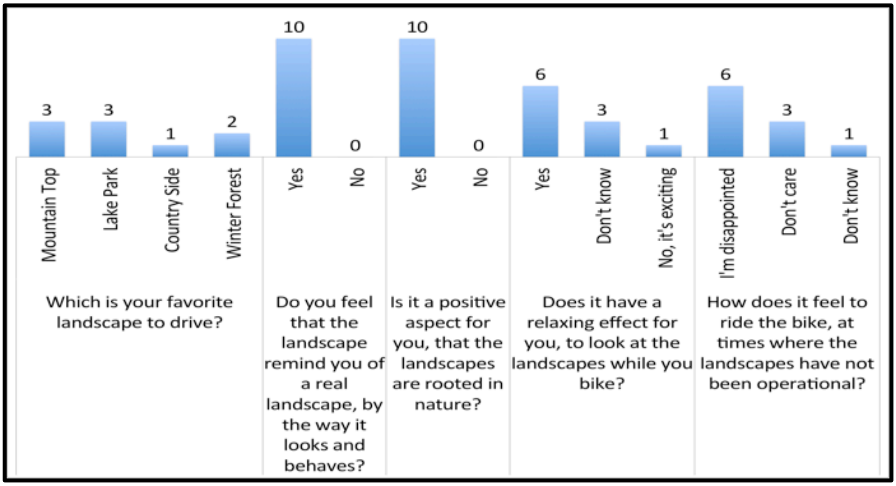

Figure 6 - S3.1 quantitative responses

For LP, near-path, edge landmarks and virtual objects (flowers, rocks, lamp-posts, bricks on the path, benches), path landmark (bridges), landmarks (waterfalls, and skyscrapers), features (sun, warmth, and colors) and 'life' (birds) were mentioned as preferences. Also mentioned was the ability to observe and experience the park from many angles, due to the LP's particular path layout type. CS only received few responses (colors and trees). No qualitative comments were made to the behavior of the RVEs. The nature-orientation of the districts was reported as a diversion from hardship and negative things and a place remote to the nursing home (indicating components *being away* and *compatibility*), cozy, pretty, lively and with movement of the surroundings, calmness, peace and happiness, lots to look at, as well as associations to the smells that real nature could provide (strongly indicating component *fascination*). *"Nature freshens the soul"* as one participant, stated. Comments to the feelings when the augmentation did not function were split (as the quantitative responses would suggest), from "*it doesn't affect me*" to "*miserable*". Three stated they would not bike without, three didn't care, and the rest would simply prefer to have it.

Responses from survey interview 2 (S3.2) were purely quantitative, and can be seen in Figure 7. As mentioned, participants were presented with items in pairs that to an extent represented each other's opposites. For example, the first two items suggested a response to the preference of looking at objects either near or distant to the path. Participants were not forced to choose between items, but simply highlight their preferences. Items asked into user preferences from four outline questions; 1] *what do you like to look at while driving through the landscape* (items 1-2), 2] *what do you find easiest to recognize* (items 3-4), 3] *what is important for your experience* (items 5-12) and 4] *what do you prefer* (items 13-20). Question 1) was based on the results from Dorwart, et al. [22] where nearby objects should have priority over distant objects.

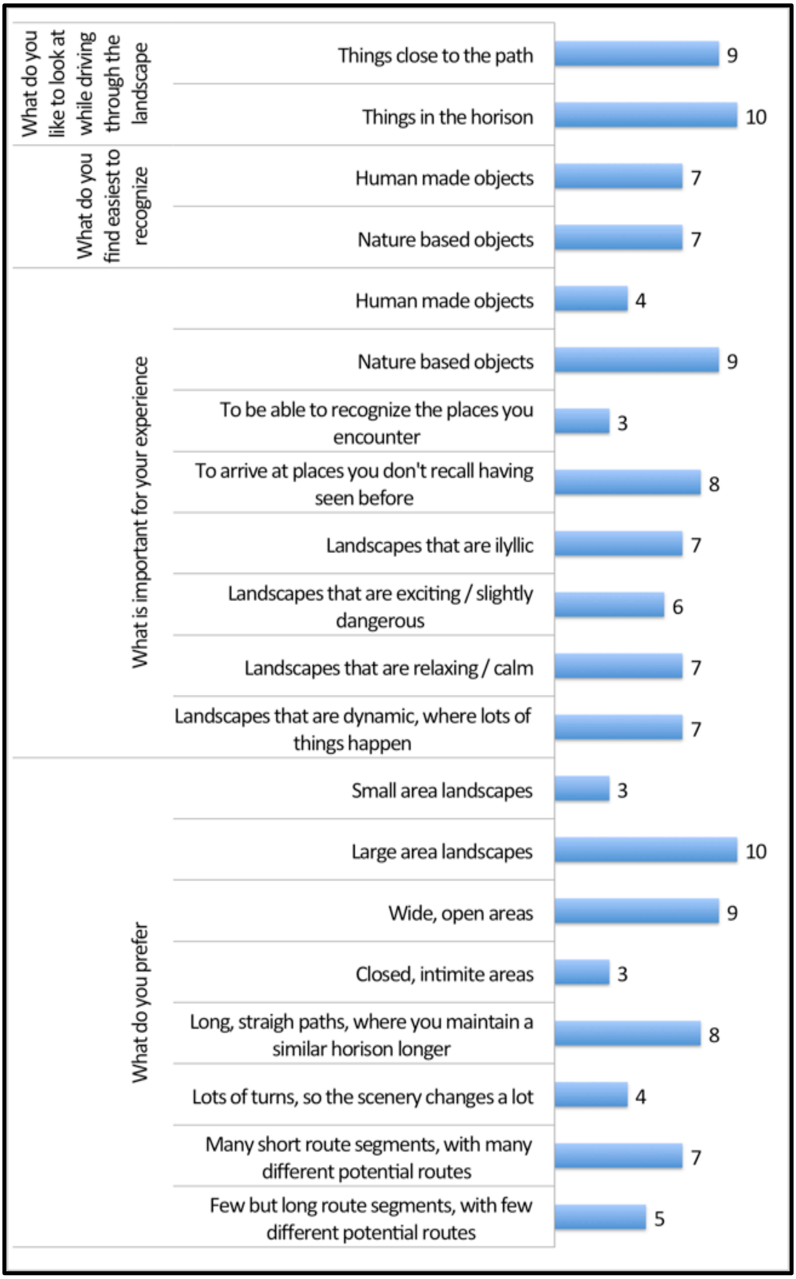

Figure 7 - S3.2 responses

With the nursing home participants, items 1-2 showed a slight favoring of distant objects, while both results were suggesting high importance, supporting the *extent* and *fascination* components. Vinson [25] suggests that landmarks should be man-made objects, as they are deemed easier to recognize. Items 3-4 indicated equal levels of recognition ease for participants, while items 5-6 showed the importance of nature- based objects to clearly exceed man-made objects.

The argument for focusing on RVE spatial recognition with man-made landmarks decrease further with items 7-8, where the majority of participant did find spatial recognition important, compared to being situated at an unknown (new) place. Items 9- 12 explored the preferences of mood orientation (idyllic, etc.) in RVEs. The user group showed no clear preference, only positive acceptance towards the suggested ache-types. Some participants mentioned that they enjoyed the ability to choose their district, based on their daily mood. Items 13-14 showed a clear preference towards *large scale* RVEs, and items 15-16 showed clear preference towards wide, open areas, supporting a preference towards having available *scenic views*. The last four items related to the path design itself, with 17-18 showing that longer, straight paths (such as MT and CS) were clearly preferable to twisty paths. Items 19-20 gave a slight indication that a high quantity of routes and junctions might be considered favorable.

Responses from survey interview 3 (S3.3) can be seen across Figures 8-13. The purpose of S3.3 was obtaining insights on RVE impactful content and characteristics for the user group by challenging their recollection of the district images. The varying degree of dementia among participants clearly showed in S3.3 results, with observably significant differences in recollection ability of specific locations and content within the district locations. Some participant showed loss of recollection towards entire districts, despite exercise logs showing proof of multiple district experiences. The quantitative results from S3.3 were treated to outline the following; a) the most recognized district based on *n* location recognitions, b) most recognized locations per district, c) the most recognized content type per district, and d) the degree of recognized landmark types across districts. Figure 8 shows the overall recognition per district. LP has best scores in all three categories, with 33% of the locations recognized across participants, 38% of the remaining locations marked with recognizable content and the lowest percentage of unknown locations at 28% between districts. The remaining three districts rank CS, MT, and WF. Figures 9-12 shows the four most recognized locations in each respective district. The S3.3 results in Figure 8 are supported by qualitative comments, in which participants reported reasons for their recognition, or the specific content recognized.

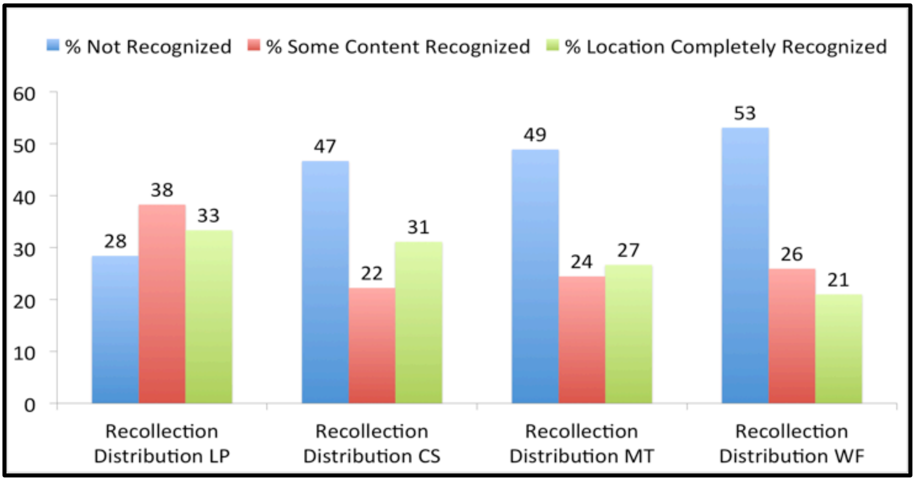

Figure 8 - S3.3 recollection results distribution between districts

Figure 9 – Most recognized location from Lake Park (LP)

Figure 10 – Most recognized location from Winter Forest (WF)

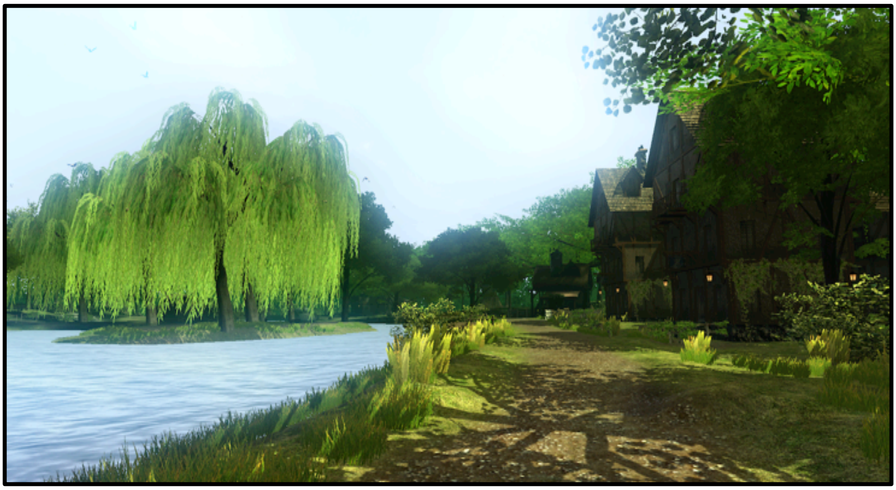

Figure 11 – Most recognized location from Country Side (CS)

Figure 12 – Most recognized location from Mountain Top (MT)

The most frequently recollected content type in LP was “flowers”, which in the displayed images predominantly represented near-path, nature-oriented details, or virtual object landmark (mentioned 16 times), with “water” (node) and “bridges” (path) both mentioned 7 times, shared as second most mentioned. For CS, the most frequently recognized content was a man-made landmark, “house” (mentioned 9 times), followed by a nature-based landmark “large willow” (6 times). MT results were dominated by the recognition of “the background” (11 times), and the second most mentioned was “the whole” (7 times) - an expression used independently by several participants, referring to the overall combination of content and in essence; the district itself. In WF, the nature-oriented detail (virtual object landmark) of “snow” was, perhaps unsurprisingly, the most recognized (14 times), with “snowflakes” (“life”) and “lanterns” (edge) almost tie for second most mentioned (9 and 10 mentions).

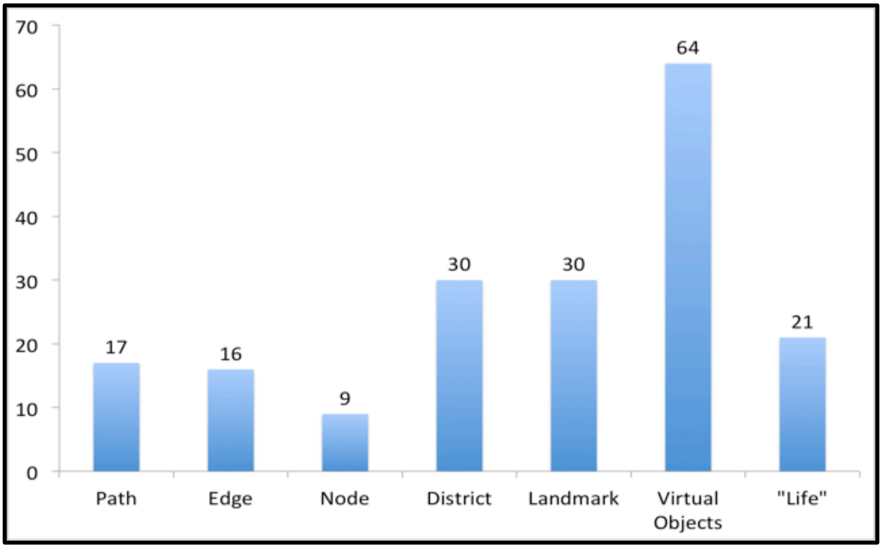

Figure 13 – S3.3 recognized landmark and nature content across districts

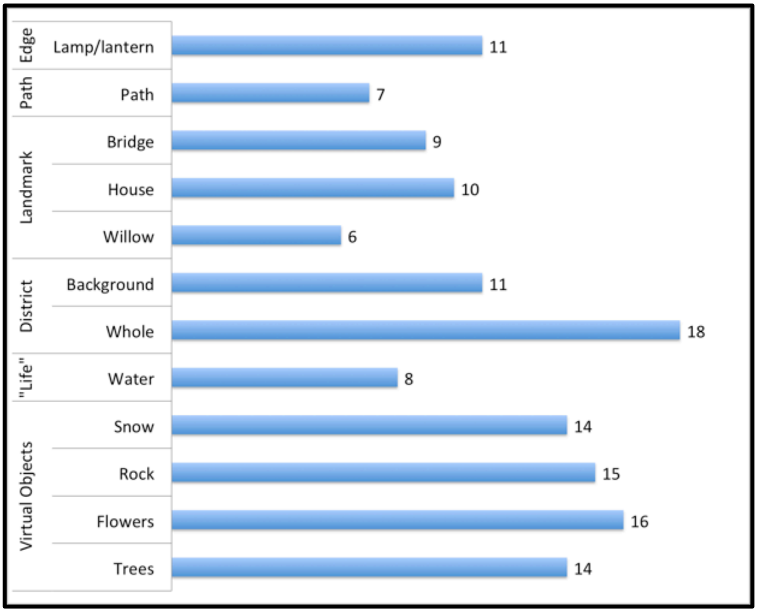

Figure 14 – S3.3 (n = 6+ mentions) landmarks and nature content across districts

Figure 13 outlines the recognition degree of each landmark and content type across districts from a recognition threshold of 6 and above. Figure 14 further details the most prominent landmark and content across districts highlighted by participants during S3.3. Virtual objects have the highest recognition score (Figure

13) and the most entry types (Figure 14). Of the 12 entries in figure 14, three (entry 1-4) are man- made, while the rest are nature-based.

6. DISCUSSION

From findings, a similarity can be seen between the most recognized locations (in Figures 9-12) for each district, and most highlighted content types between districts (Figure 14). It indicates that a variety of content can be more memorable with the resident users, and highlights that while there are similarities, the same content types are not necessarily focal points for all RVE designs. The coded results in S1 and S2 suggest that Kaplan's components show in resident experience with the RVEs, and also that the components can structure restorative experience types not directly related to specific content or features. Due to the different orientation of the two studies, responses are differently oriented but suggest that the display technology could have an effect on the perception of content. Participants in S1 give an impression of passively observing the RVE and its content, as a positive addition to the manuped exercise. Participants in S2 express their experience as if situated inside the RVE. Increasing the immersive properties with an HMD objectively allows more of the RVE to be viewed and explored. Dynamic content types such as wildlife play a different role when the user can follow and observe it due to enabled visual orientation. Meanwhile, the responses in S1 and S2 are taken out of their original context. In the frame of this paper, S1 and S2 should be seen only as supporting the notion that restorative experiences seem possible in VR, and as an indication that the immersive properties of the system might affect the degree of that sensation. However, the goal in [18] was to measure the effects on intrinsic motivation following increases in immersive system properties, not directly to measure the restorative potential so that no conclusions can be made. Responses in S2 were dominated by the *being away* component, which leaves much to be desired about the perception of content, and details about the sensation of nature. It can hypothetically be argued however, that since the recreational experience forms the main addition to the reported increase in intrinsic motivation to exercise for residents, and a higher sense of presence led to a reported increase of intrinsic motivation, that the sense of presence and the impact of the restorative experience might be connected. But more support for this should be considered for a future study.

From the survey interview data, the role of nature as the situation of the VE augmentation was confirmed to be positive for residents, with the majority of residents reported to perceive the VE nature settings to have a relaxing effects, but all supporting the overall RVE behavior as realistic. Responses indicated that the augmentation provided user experience aspects related to Kaplan's four components, such as *being away,* in a place outside the '*hardship and negative things'* of nursing home living, with the descriptions of the RVE districts given very positive descriptions in comparison, easily relating to Kaplan's *extent* and *fascination* components. This is encouraging, as the restorative components are regarded (in this paper) as the overall orchestration method of the RVE design. This relates to the type of restorative user experience that the augmentation should pursue. The majority of participants reported disappointment, when not able to access the augmentation for manuped exercise.

S3.2 had useful results regarding confirming and discarding different design choices that could otherwise have been an open question in future RVE designs and implementations. Depledge, et al. [6] state that content is critical for environment engagement, which is reflected in S3.2 user responses, showing that distant or near, content is looked for when experiencing the RVEs. However, the paradigm of Vinson, where man-made landmarks are almost the only choice, S3.2 results show that participants reported recognition ability to be equal between man-made and nature-based landmarks, and additionally reported a preference towards nature-based content as opposed to man-made. Results showed no support for considerations of navigation guidelines the RVE design, for area recognition purposes for nursing home resident, Only performance from a few participants suggested that area recognition as an important factor for their experience, and most responses showed preferences towards venturing into unrecognizable areas. Results showed an equal acceptance between idyllic/calm and exciting/dynamic moods. Meanwhile, large and open (scenic) RVEs were clear preferences, with long straight paths, e.g. similar to MT and CS.

From Figure 8, LP stands out as the RVE from which participants had least difficulties recollecting content. Curiously, CS is second, with MT a close third. Despite being minuscule with many design limitations related to its size, CS was very well received. In the overall exercise log, (which is not explicitly documented in this paper), CS it is more clearly the second most used RVE after 10 months of augmentation usage at the Akaciegården, based on the total number of exercises, total distance covered, and total time spent inside the RVE in the 10 months. MT is also third after CS, while LP is a clear winner in all categories with 25-33% higher scores on all parts compared to CS. Reasons for the distribution might be visible from S3.3, Figure 13, where virtual objects are by far the most recognized RVE content. Figure 14 supports how flowers, trees, rocks and water are all top tier natural content types. These amount to a substantial part of LP content in general. Besides, three of the top four man-made RVE content types in Figure 14 (path, bridge, lantern) are also inherent to LP. The reasons for CS's position as second most popular RVE might be found in the same combination user recollections (only exchanging 'lantern/lamps' with 'house' as the man-made landmark type). The results from Figure 8, showing residents' general lack of ability to recollect specifics despite their experience level with the RVEs. Before these results, it was not expected that MT would be less popular than CS, with many design related advantages that should theoretically defend expectations for MT being more popular than CS. MT is much larger than CS, and has more diverse scenery, is very scenic value oriented, and with numerous dynamic, exciting events (waterfalls, large bridges, wildlife, sloped paths, a more advanced path system, and intense vistas), as indicated by both Figure 15 and Figure 16.

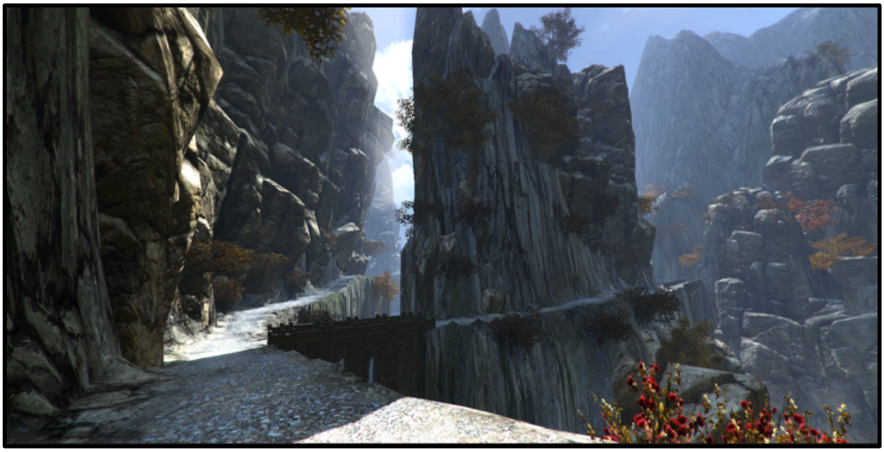

Figure 15 – MT has an advanced design with dynamic content/features like wildlife, strong winds, birds, sloping paths, waterfalls, and large cast shadows.

Figure 16 – MT is very vista oriented, but has little ground based content.

Lighting, shadows, and path design are more sophisticated, and MT has more nature landmarks and distinctive nodes for travel than CS, while retaining regular ‘soft fascination’ areas throughout its path range (as seen in Figure 16). The intricacies of its design invite for exploration.

Figure 17 – The calm, green and friendly RVE content design of CS.

CS however, has more 'apparent' wildlife due to the combination of its large bird flock and small size environment. It is very calm, the path design is smooth, it is consistently picturesque and green, has constant visual contact with water, large quantities of plant life, and 'cute' buildings, such as seen in Figure 17. MT might have the inherent 'problem' of being too exiting to be anyone's choice. As one participant noted, when describing MT as her favorite "*Trees, things in the side, excitement when you think you are about to fall off the cliff, open spaces where something happens, and something to look at*". However, the results for MT remain positive. An interesting detail to MT is the two most mentioned 'recollections' – "the whole" and the "background" (the latter responses came from items showing accessible path locations). Both recollections relate to the 'entirety' of the experience, and presumably speak to MT's content synergy or *coherence* (from Kaplan), more than particular parts. The defining feature of this RVE is thus, reportedly, its district identity, more than one individual content type. And while Figure 7 suggests that both nearby and distance are important, MT results show that it very well could depend on the overall design idea and expression of the RVE. And how participant evaluations rely on the 'whole', more than results directly indicate. There were many flowers in CS, but these were practically not mentioned in the comments, which could stem from residents not considering them as the leading 'representatives', or *thematic core* of that RVE design. In LP, the maintenance and grooming of the nature content (flowers, trees, rocks) is a high priority part of the RVE thematic core, and the most mentioned content by far. The most reported content element in CS were the big willows and large houses - all dominant in size for the small RVE, and thematically logical as thematic parts of the design. But it is striking how reports are missing of the (between RVEs) most valiable content, in the most popular RVE. The lowest ranking of WF is not directly apparent in the results, but based on the previous part of this discussion, it could relate to WF's even larger absence of plant-based, nature-oriented details, despite its attempt to offer a different, but equally nature- oriented setting. As described in Methods section, the lack of color palette in WF's virtual objects might have created recognition problems, in relation to appropriately differentiating areas from each other. In retrospect, WF should have been even better at this task, as the lack of vistas and overview (due to the more intimate locations), combined with the limited color and nature object palette should, logically, place higher requirements on the demand for an individuality of the areas. WF did have many individually distinct nodes and other landmarks, but seems not to attract users as well as the other RVE. Exact reasons might become clearer in future studies.

For future RVE designs for nursing home residents, it would be interesting to put these results into practice. RVEs for residents might not need the complexity of the designs shown in this paper. They might not need the focus on landmarks, but more on overall nature 'themes' based on rich, lush virtual objects, where the 'whole' that should be the priority, more than the individual landmarks. Instead of spending resources on into one RVE, with lots of diversity from many detailed landmark locations, the developer might more efficiently make several RVEs, based on individual themes, with simpler content and less diversity. It might give residents the impression of a more diverse offering, by the increased quantity of locations to visit, while theoretically offering the same valiety, just spread over three RVEs instead of one. In hindsight, this might be logical. While residents responded that they preferred to experience new locations compared to recognizable ones, and while this is most certainly their opinion, the years spent observing residents at Akaciegården indicate that many nursing home residents forget many things they have experienced, and thus don't mind repetition and routines. Dementia plays a large part in any result relating to nursing home residents, including the results in this paper. But which role it plays and how much it means, is speculation at this point.

7. CONCLUSION

The purpose of this paper has been to establish and evaluate design recommendation for the development of custom, recreational RVEs, for the purposes (in the context of this paper) of being a motivational contributor for older adult users at nursing homes. Previous studies [17] [18] have shown that the RVEs are in fact motivational for this user group, based suggestively on the user experience of its content. This study has presented and evaluated its design approach, based on the user experience of four individual RVE designs approach to the RVEs, and investigated the user preferences by various forms of RVE content. It has also presented some input to suggest potential focal points for future RVE design. Results suggest that nature experiences are important motivators to exercise, and that lush plant-based content is relevant for the preference of older adult users. More work on the subject remains important, to further understand the user experience of older adult users, in relation to what makes individual content stand out in memory. There might be a relationship between the overall thematic directions of an RVE, and the recollection and preferences of particular individual content types in an RVE, when designed for nursing home residents.

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