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Restorative Virtual Environment Design for Augmenting Nursing Home Rehabilitation

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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 aging. This is 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. More studies on content of proper custom designs for RVEs are 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.

1. Introduction

Deceleration of physical ability increases with age and affects health and everyday life quality (Kofod, 2008). 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, prevent sarcopenia, and add general health related benefits (Landi, et al., 2010) (Mazzeo & Tanaka, 2001). Many residents never engage in in-house physical therapy clinics, making every-day independent tasks, such as getting dressed or eating, impossible. Studies highlight numerous benefits of nature. Nature is a motivation factor for physical activity and an activity choice for wellbeing (Irvine, Warber, Devine-Wright, & Gaston, 2013) (Depledge, Stone, & Bird, 2011) (Kaplan, 1995) (Taylor, Kuo, & Sullivan, 2002) (Herzog, Maguire, & Nebel, 2003) (Kort & IJsselsteijn, 2006) (Kahn, et al., 2008) (Ulrich, et al., 1991). Virtual Environments (VEs) can connect real world actions and virtual world reactions, comparable to real world situations. Health-oriented deprivations of residents' independent travel outside the nursing home prevent their experience of real nature-based environments. VEs represent an increasingly mature technology for facilitating nature experiences, e.g., for recreational exposure benefits (Depledge, Stone, & Bird, 2011). This paper is the most recent in a series of investigations into augmenting a bike-oriented, indoor exercise routine for older adult nursing home users, displaying nature-oriented VEs to increase motivation towards regular exercise. The goal of the paper is to enclose the dominant parts of that recreational experience for nursing home users, based on four nature-based VEs, designed for restorative effects in the virtual domain, and suggest how to design for such impact on the user experience.

2. Background

Recent studies at Akaciegården nursing home (Denmark) (Bruun-Pedersen, Pedersen, Serafin, & Kofoed, 2014) (Bruun-Pedersen, Serafin, & Kofoed, 2016a) (Bruun-Pedersen, Serafin, & Kofoed, 2016b) have indicated usefulness of multimodal virtual environments (VEs) to augment bike-reminiscent for increased exercise motivation. The augmentation maintained the exercise routine fundamentals but added the user experience of a recreational ride in a nature-based, restorative VE (RVE). When pedaling, the virtual camera moves forward along a fixed path, to suggest forward driving in the VE. Participants enjoyed the possibility of travelling to another place and explore 'beautiful' nature content. Studies on nature exposure show how it can produce relaxation, induce positive mood, recover attention capacity, cognitive function, reduce stress, and more (Depledge, Stone, & Bird, 2011) (Kaplan, 1995) (Taylor, Kuo, & Sullivan, 2002) (Herzog, Maguire, & Nebel, 2003) (Bratman, Hamilton, Hahn, Daily, & Gross, 2015) (Irvine, Warber, Devine-Wright, & Gaston, 2013). The term *restorative* is used in identical fashion as *recreational*, the trend being the former used predominantly in medical or physiological relations (Kaplan, 1995) (Herzog, Maguire, & Nebel, 2003) (Kort & IJsselsteijn, 2006), and the latter referring primarily to leisure activities, nature environments or tourism (Dorwart, Moore, & Leung, 2009) (McKercher, 1996).

Depledge, Stone & Bird suggest that high-fidelity, ambience-rich VEs are becoming important for allowing disabled or elderly individuals convincing nature experiences, by the evolution of affordable, contemporary VE and virtual reality (VR) hardware and software, (2011). Establishing a design methodology on custom RVE design, especially for non-architect designers and developers, shows how literature is very sparse (Bruun-Pedersen, Serafin, & Kofoed, 2015). In fact, VEs in rehabilitation studies mainly serve a casual ambiance role for a primary task (Cameirão, Badia, Zimmerli, Oller, & Verschure, 2007) (Shema, et al., 2013) (Norouzi-Gheidari, Levin, Fung, & Archambault, 2013). Many studies that use VEs designs for central parts of their work (Deutsch, et al., 2012) (Nurkkala, Kalermo, & Jarvilehto, 2014) (Baños, et al., 2006) (Karjalainen & Tyrväinen, 2002) (Wargnier, et al., 2016), omit comprehensive findings on the role of VE or RVE content design specifics. The minimal body of work on the cues and clues that trigger human interest and

sense of wellbeing in nature environments (real or virtual) is currently an issue for RVE development (Depledge, Stone, & Bird, 2011).

Design and development require a combination of considerations, for example; real world environment realism replication in VR (Kort & IJsselsteijn, 2006) (Nurkkala, Kalermo, & Jarvilehto, 2014) (Koenig, Dünser, Bartneck, Dalrymple-Alford, & Crucian, 2011) (Hall, 1990), tourism and recreational experience design (Depledge, Stone, & Bird, 2011) (Koenig, Dünser, Bartneck, Dalrymple-Alford, & Crucian, 2011) (Dorwart, Moore, & Leung, 2009), urban design and urban planning in VE (Sangani, et al., 2012) (Lange, 2001), and spatial recognition for navigation in VEs (Vinson, 1999). Based on this, RVE design considerations can be condensed to its *components, content, features*, and *spatial structures* of content placement in the RVE.

2.1 Restorative VE Components

According to Kaplan (1995), the restorative aspects of (non-VE) nature settings can be understood from a perspective of *attention* as a finite resource that needs periodical 'resting' from demanding environment influences. Certain types of natural environments can be restorative for attention resources, if inherently delivering experiences reflecting 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"* (Kaplan, 1995). 3) *Fascination;* which for nature settings is predominantly a 'soft' fascination, as opposed to 'hard' fascination from adrenaline producing experiences. It is obtained through contents or settings that do not require *directed* attention (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 (Kaplan, 1995).

2.2 RVE Content

Content in RVEs is critical, with water as particularly important for restoration (Depledge, Stone, & Bird, 2011). 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 (Depledge, Stone, & Bird, 2011). A visitor behavior study examined perceptions and preferences of visitors at the Great Smoky Mountains National Park trail tour (Dorwart, Moore, & Leung, 2009). Results show how nature-oriented details (plants, wildlife, forest, rock formations, and combinations of such for close user inspection inspire exploration) were most important to users' recreational experience. Also important are scenic values (broad views, distant locations overview, high altitude vistas of trees and beautiful scenery, light and shade combinations, and 'natural elements', waterways and waterfalls). Management influences (man-made objects) should blend into the environment, while depreciative behavior (litter, trash, general destruction of natural content) was a negative predictor (Dorwart, Moore, & Leung, 2009). 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.

2.3 RVE Features

RVE features cover both technical and artistic RVE considerations. Photorealistic rendering would induce an ecological experience, but require unrealistic contemporary computational demands. Some aspects of realism prevail over others, and multimodal VEs do not need

photorealism to achieve convincing perception of realism (Ijsselsteijn, Nap, de Kort, & Poels, 2007). Correct imagery and geometric detail are not implicitly required for a perceptual impression of realism (Lange, 2001), but the behavior of the VE must be reasonable to the user. High image complexity, subtle shading and rich surface detail are central for the perception of realism (Hall, 1990). 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 (Kort & IJsselsteijn, 2006). *RVE feature* considerations thereby relate to technical aspects of the RVE and its content (environment behavior, rich surface details, high resolution textures). This also count for 'artistic' design choices (scale, lighting, shading, complexity) to achieve the important effects for perceived 'recreational realism' by how features combine with content. 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 (Lange, 2001).

2.4 RVE Spatial Structures

Vinson (Vinson, 1999) proposes *VE navigation guidelines* from a landmark typeset, of unique reference points, making area identification easier. 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 (Vinson, 1999). Individual landmarks need detail variations such as height, shape, etc. to make them distinguishable (Vinson, 1999). 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.

The landmark typeset aid an RVE design by top-down macro-or bottom-up micro processes. Top-down mapping is useful when keeping organization to place landmarks evenly throughout an RVE and ensure proximity to typical user placements. 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 (Totten, 2014). A diagram example used for four RVEs is presented in Figure 5. Moving through a landscape and viewing it from many different angles can change the perception of the landscape drastically (Karjalainen & Tyrväinen, 2002). 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 head-mounted display (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.

3. RVE Implementations

Kaplan's four components should orchestrate the general direction of the experience, built using *RVE content, RVE features* and *RVE spatial structures.* Four RVEs were implemented following the pilot study. The RVE's identities were based on user responses from a previous study (Bruun-Pedersen, Pedersen, Serafin, & Kofoed, 2014), availability of 3D assets for the chosen game engine platform (Unity 4 Pro) appropriate to support a restorative experience. 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 with nursing home residents. In a pilot study, using a trivial RVE displayed on a 46' LCD TV, subjects reported "*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*" (Bruun-Pedersen, Pedersen, Serafin, & Kofoed, 2014). A similar effect should thereby be anticipated in new designs, where 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 (Dorwart, Moore, & Leung, 2009)). 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 software, restorative insights from literature and use of RVE features. Landmark, virtual object placement, and path grids were performed in parallel for each district, aided by a central 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 (1995).

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 districts 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.

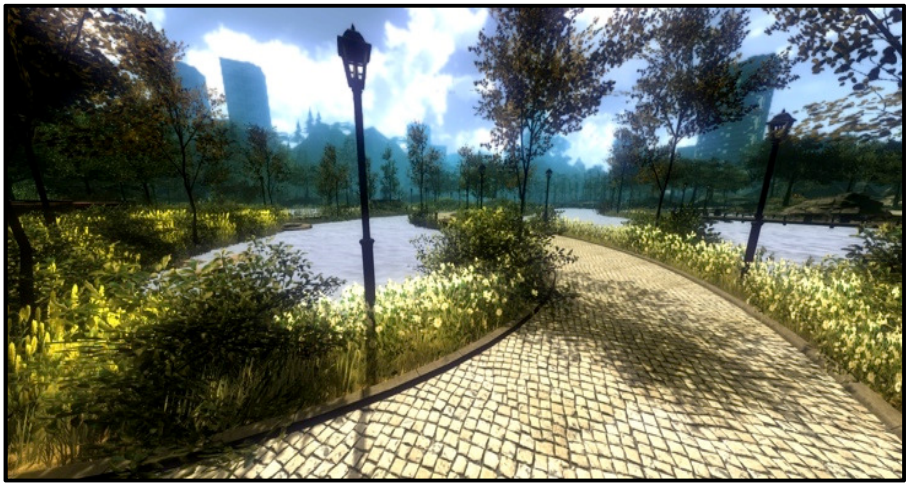

Figure 1: Screenshot from Lake Park RVE

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.

Figure 5 provides a top-down diagram mapping of the four districts (what Totten refers to as a molecule diagram (2014)), 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). Path size is narrow to intimate, depending on 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').

In Figure 5, the landmark type path in the diagram is the path grid, while many edges (e.g. fences) are not represented in an obvious fashion. 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, 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.

4. Methods

The RVE designs discussed in this paper were used for exercise by nursing home residents for more than 10 months before this study. Past research (Bruun-Pedersen, Pedersen, Serafin, & Kofoed, 2014) (Bruun-Pedersen, Serafin, & Kofoed, 2016a) (Bruun-Pedersen, Serafin, & Kofoed, 2016b) has presented user responses concerning the exercise augmentation, but the RVE design considerations

in this paper have yet to be evaluated. The first part of the RVE design measure, reviews user responses recorded in two previously performed studies (Bruun-Pedersen, Serafin, & Kofoed, 2016a) (Bruun-Pedersen, Serafin, & Kofoed, 2016b), related to the design considerations described in this paper. These studies will onwards be referred to as Study 1 (S2) and Study 2 (S2). The second part is a series of survey interviews performed exclusively 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

S1 focused on measuring changes in intrinsic exercise motivation over a four months period (Bruun-Pedersen, Serafin, & Kofoed, 2016a). S2 focused on the effect on intrinsic motivation as a consequence of changes to the sense of presence from increasing immersive system properties (Bruun-Pedersen, Serafin, & Kofoed, 2016b). While the premise, methods, participant group and visual display technology was different between S1 and S2, both procedures focused on qualitative, open-ended responses concerning the user experience with the four RVEs. The system setup for S1 was using a 46' LCD TV for the visual display, whereas S2 was using an Oculus Rift DK2. In this paper, original 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

The survey interviews used a questionnaire, with 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?), and hints to possible restorative effect of the experience. For instance whether it was important to residents, that VEs were nature-based (why?), if the RVE provided a sense of relaxation (a restorative indication), and if it had been upsetting for the participant when the RVE augmentation had sometimes been unavailable.

The second survey interview (S3.2) had 20 items, for gaining more, general insights to preferences and perceived importance from user experience on 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 choose 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.

This approach was exploratory. The logic was that for dementia-affected nursing home residents to want to return to a place (for exercise), they would have to remember something from it. The landmark typeset is meant to increase recognition, which could help the variously demented residents remember their RVE experiences. S3.3 attempted to qualify and quantify which landmark types, spaces or smaller content details were considered memorable by participants. This should indicate which content types should be considered a priority for future RVE designs. 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 to 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. (2011) 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 Content	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 downhill! * 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 all participants accepted the behavior of the RVEs as 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"*.

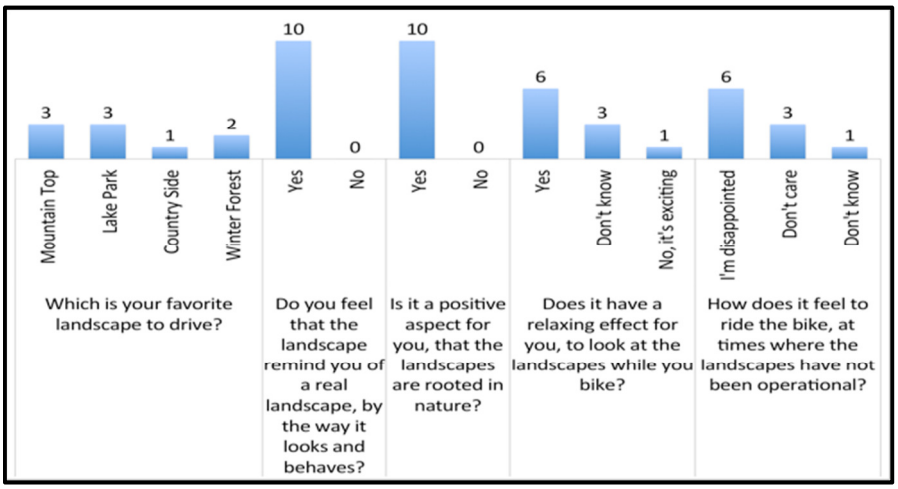

Figure 6: S3.1 quantitative responses

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.

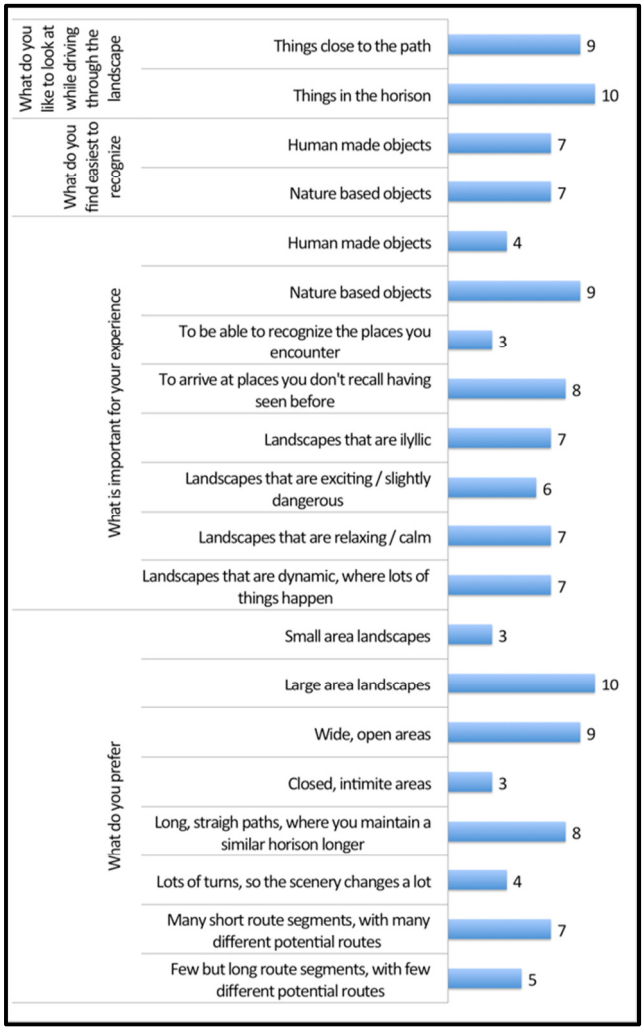

Figure 7: S3.2 responses

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, Moore, & Leung (2009), where nearby objects should have priority over distant objects.

Items 1-2 show a slight favoring of distant objects, while both results were suggesting high importance, supporting the extent and fascination components. Vinson (1999) suggests that landmarks should be man-made objects, as they are deemed easier to recognize. Items 3-4 indicate equal levels of recognition ease for participants, while items 5-6 show the importance of nature-based objects to clearly exceed man-made objects.

The argument for focusing RVE design on spatial recognition, using 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 explore 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 show a clear preference towards large scale RVEs, and items 15-16 show clear preference towards wide, open

areas, supporting a preference towards having available scenic views. The last four items relate 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 give 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 show 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 show the four most recognized, unique location 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.

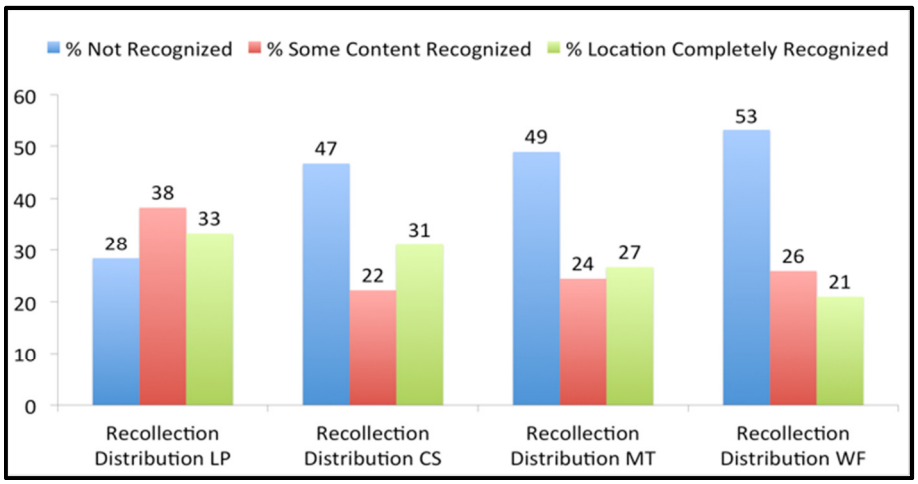

Figure 8: S3.3 recollection results distribution between districts

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

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

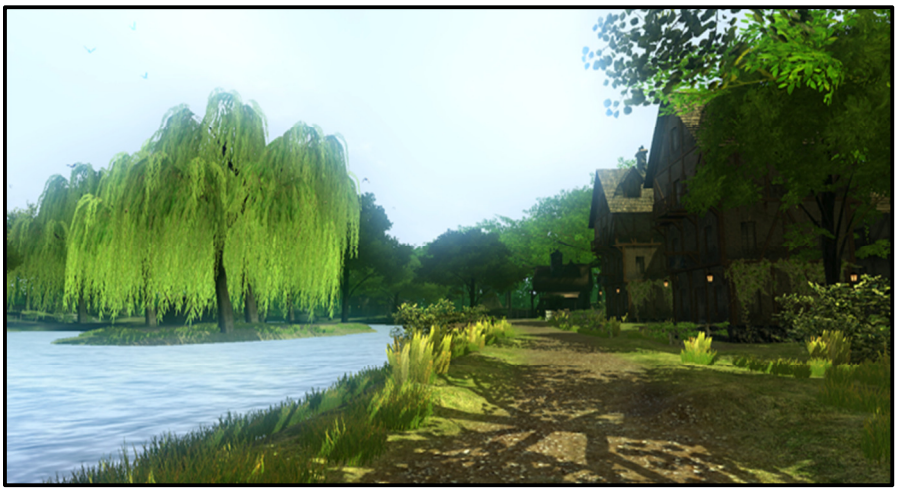

Figure 11: Most recognized location from Country Side (CS)

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).

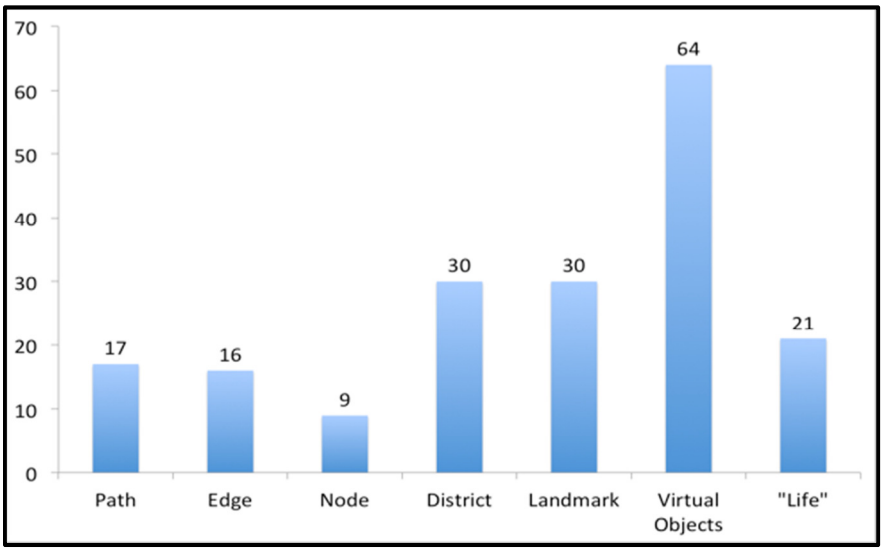

Figure 13: S3.3 recognized landmark and nature content across districts

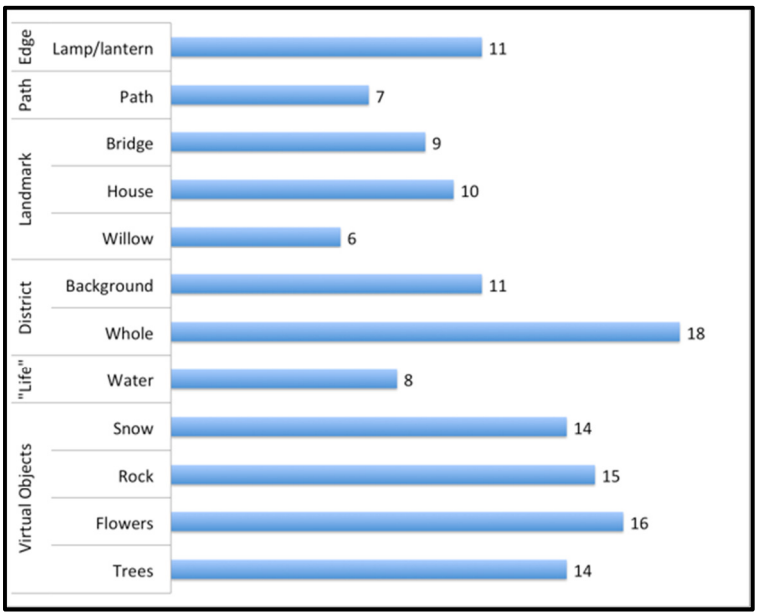

Figure 14: S3.3 (n = 6+ mentions) landmarks and nature content across districts

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 outline restorative experience types not directly related to specific content or features. Due to the different individual orientation of S1 and S2, 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 (Bruun-Pedersen, Serafin, & Kofoed, 2016b) 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, Stone, & Bird (2011) 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 (1999), where only man-made landmarks are the correct 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 residents. 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.

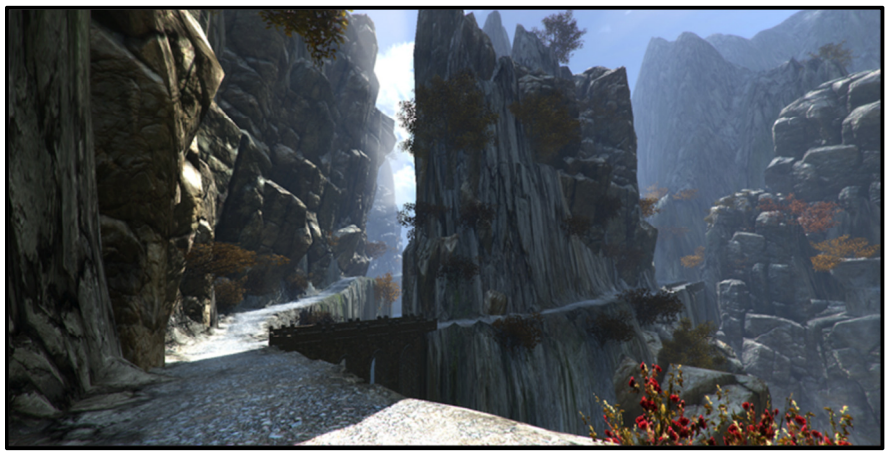

Figure 15: MT has an advanced design with dynamic content/features like wildlife, strong winds, birds, sloping paths, waterfalls, and large cast shadows.

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.

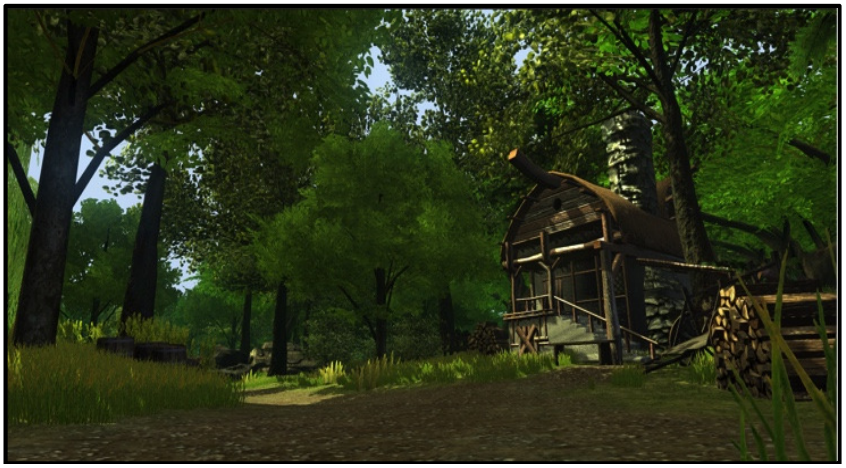

Figure 17: The calm, green and friendly RVE content design of CS

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 valuable 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 validity, 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 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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