Council of Coaches in Virtual Reality

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Abstract

The life expectancy is increasing but the healthspan, the lifetime of good health, is not developing with the same trend. The spending on health care has continued to increase across the EU and with an ageing population the burden on health care spending will increase further.

Research has shown that a healthy lifestyle substantially contributes to the prevention of civilisation diseases and reduces their effect on the quality of life. The problem with most of the applications that focus on personalized coaching and change behaviour is that they are focused on a single domain, target a young and already active group and are missing the ability to engage the users over a longer period.

To address the problems with current coaching and supporting applications, a new concept of virtual coaching was announced, called the "Council of Coaches (COUCH)". It is a concept that is focused on integrating different domains and offer support and knowledge to change behaviour and improve the health of users. COUCH is an autonomous, multiagent and interactive demonstrator that allows the user to participate in a virtual council meeting to motivate and inform about health and wellbeing related issues, including physical, social, cognitive and mental support. The council meeting will take place between virtual characters and the user.

This research aims to determine how a new 3D modelled environment can influence the engagement of older adults with the COUCH system in Virtual Reality (VR). Based on the related work, a literature review, user confrontation and user scenarios four different prototypes were made, called Beach2D, BeachVR, Forest2D and Forest VR. Three studies were conducted to evaluate the effect of the different components in the screen-based prototypes, the difference in experience between the screen-based and VR prototypes and the effect of the different components in the VR prototypes. Analysis of the three studies demonstrated a recommendation for the forest environment in VR. The forest environment was preferred because of the looks, feeling and view. The VR was preferred because it was seen as more realistic, giving a better experience and more

immersion. The participants preferred the outdoor experience because of the unlimited view. This research found that the engagement of older adults with the COUCH system in VR can be influenced by the use of different environments, sounds, interaction mechanisms, screen-based or VR experience, indoor or outdoor experience, the use of a couch, table and different chairs.

Acknowledgements

First of all, I would like to thank my supervisor Randy Klaassen and my critical observer Daniel Davison for their support, guidance, feedback and help throughout this graduation project. I would like to thank the Creative Technology faculty and staff for the past three years. I am grateful for the support that I received from my family and friends. Finally, I would like to thank all the participants that helped me during this graduation project.

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1 Introduction

1.1 Developments of health care

The life expectancy is increasing significantly in the European Union (EU), but the healthspan (the lifetime of good health) is not developing with the same trend [1]. The spending on health care has continued to increase across the EU as a proportion of national income and with an ageing population and thus the possibility of elderly people around, the burden on health care spending will increase further [2]. This leads to an expected doubling of the costs by 2050 due to health, social care and pension consequences [1].

Given the demographic developments, separating trend between life expectancy and healthspan and the pressure on affordability, it is important to understand the factors affecting old age health and establish and support preventive measures and policies to ensure that more of our older adults achieve healthy and active ageing [2]. Mortensen [2] showed the importance of public health programs in combating the health issues of various societies. Programs that focus on promoting health and healthy lifestyles, like avoidance of smoking, better nutrition, less alcohol consumption are effective for the prevention of civilisation diseases. The rapid ageing of the population has set the focus of expenditure on prevention of disabilities related to chronic diseases [2]. The health care in the EU is a system that is a complex, dynamic and adaptive system that faces many challenges because of these demographic developments, rising competition and new technology opportunities. Enhancing the health care sector is needed if Europe wants to sustain its global market competitiveness and remain a healthy, equitable and prosperous place to live [3].

1.2 The need for e-health integration

These demographic developments, separating trend between life expectancy and health span cause an increase in older adults living with the effect of various chronic conditions. There is no cure for these conditions, but a healthy lifestyle substantially contributes to their prevention and reduces their effect on the quality of life [1]. Embracing a different healthier lifestyle

requires a change in behaviour. Changing behaviour is difficult without the appropriate support and knowledge [1].

A better understanding of integrated care and the improved management of care processes will be crucial in responding to the challenge of the increase in older adults living with the effect of various chronic conditions. Concerning process design, service delivery, skills mix, the participation of patients, funding flows and regulatory requirements much more has to be learnt and it is important that the creation of IT that enables connectivity, alignment and collaboration between the different health domains is established [4]. The integration of care proposes advantages for patients and health and social security systems in the EU and the integration drives greater e-health synergy by improving e-health compatibility [5]. These information technology-based resources improve health care organization performance and hospital performance [5].

Applications that focus on personalized coaching and change behaviour are increasing on the market and in some domains, it has penetrated the market. The physical activity domain is an example of this market penetration and has applications that monitor and coach on activity, nutrition and exercises among other things. The problem with the most of these applications is that they are focused on a single domain, target a young and already active group and are missing the ability to engage the users over a longer period [6]. To address the problems with current coaching and supporting applications, a new concept of virtual coaching was announced, called the "Council of Coaches". It is a concept that is focused on integrating different domains and offer support and knowledge to change behaviour and improve the health of users.

1.3 Council of Coaches

Council of Coaches (COUCH) is an autonomous, multiagent and interactive demonstrator that allows the user to participate in a virtual council meeting to motivate and inform about health and wellbeing related issues, including physical, social, cognitive and mental support. The council consist of several Embodied Conversational Agents (ECAs) and each virtual character

has its expertise, personality and style of coaching. The expertise is on various domains including physical activity, cognitive and mental health, social skills and participation, as well as condition-specific expertise for diabetes and chronic pain [6]. The council meeting will take place between the ECAs and the user. The coaches consist of a diet, physical activity, mental, social coach or a peer. These coaches interact with the user and each other to inform, motivate and discuss issues to the user's health and well-being. The coaches will listen to, inform, help and motivate the user to set and pursue goals to improve their health. The user than share its developments and questions with the council or listen and observe how the different virtual characters discuss their opinions. The user can use the suggestions and lessons in its daily life and contact the virtual characters anytime, anywhere. In the version of January 22, 2019, the Greta and ASAP platforms are used for multimodal behaviour generation and for visualising Embodied Conversational Agents (ECA) into the Unity3D engine. The screenshots below show the current design (version January 22, 2019) of the characters and environment [16]. COUCH takes the next step to integrate different health services to provide older adults with a personal integrated coaching experience and improve the affordability of health care, increase the quality level of health care and increase the efficiency of the deployment of health care workers.

Figure 1: Screenshot of the COUCH agents [16]

Figure 2: Screenshot of the COUCH agents [16]

1.4 Virtual Reality and potential application for COUCH

Virtual Reality (VR) is an "immersive human-computer interaction in which an individual can explore and interact with a three-dimensional computer-generated environment" [7, p 225]. Usually, it is assisted through a head-mounted display that replaces the real-world physical view of the user with an interactive computer-generated environment. The VR technology is used in the medical, automobile, driving training, flight simulation, architecture design and military training field [8]. VR is an effective way to teach physical health and it has a positive impact on the doctors and the users [8]. It changes the way users do the exercise, has a significant effect on exercise routine, leads to better results, can help users with pain issues, allows users to exercise in a virtual and safe environment, can track the body movement and enables interactive exercises for the users [8]. VR allows doctors to view a virtual model of the patient, can be used to analyse the pain of the patient’s body, enables training possibilities and creates better surgical techniques [8]. VR technology offers new opportunities and helps the patient' experience of treatments. It can help release stress by allowing the user to experience the real-life experience in a virtual simulation [9]. VR can give a better perception of the surrounding environment, allows for immersion into situations and can resemble virtual motion and experience to the human brain [9].

1.5 Goal and research questions

The current prototype and demonstrator of the COUCH system are focused on and designed for the screen-based interaction between the user and the system. The first developments in prototyping COUCH in Virtual Reality are done but so far, the 3D environment lack a background, attributes and

the virtual characters are in a fixed position. With the use of Virtual Reality, the interaction of the user and could be made more immersing, imposing and possibly more engaging. Considering the screen-based interaction version of COUCH and the potential benefits of VR on the human-computer interaction of COUCH, it is interesting to integrate and improve the Council of Coaches system in VR with the target group of older adults in mind. Older adults have less experience in using technology, especially Virtual Reality. Next to that, older adults sometimes have negative attitudes and health implications, like visual impairment, hearing limitations and fine motor difficulties that affect the interaction with technology [10].

Different aspects are needed for the transformation from screen-based interaction to VR. In this project, the goal is to design a 3D environment for COUCH in VR that fits the target group of older adults and to test the developments on older adults.

After researching, the problem and understanding the project background, research questions are constructed and stated hereafter:

Main question:

- How can a new 3D modelled environment influence the engagement of older adults with the Council of Coaches system in Virtual Reality?

Sub questions:

- What are the factors influencing the engagement of older adults with Virtual Reality?
- What are the factors influencing the engagement of older adults with the Council of Coaches system?
- What factors of the 3D environment are influencing the engagement of older adults with the Council of Coaches system in Virtual Reality?

This report consists of four parts. The first part is the State of the Art, which builds on the introduction and includes a review of relevant literature and related work. The second part consists of the ideation and specification

phase where new design ideas are formed and specific requirements are described. The third part consists of realisation and evaluation. The last part consists of the conclusion, discussion and description of future work.

2 Background

This section will give an overview of the existing projects and products that are related to this project. After discussing the related work and the advantages and disadvantages, opportunities for improvements could be identified. Next to that, this section will give an overview of relevant literature for this project and how this literature can be used in the project.

In this section the goal is to answer the following sub research questions.

- What are the factors influencing the engagement of older adults with Virtual Reality?
- What are the factors influencing the engagement of older adults with the Council of Coaches system?

2.1 Related Work

Council of Coaches (COUCH) is an autonomous, multiagent and interactive demonstrator that allows the user to participate in a virtual council meeting to motivate and inform about health and wellbeing related issues, including physical, social, cognitive and mental support. In this section the preceded technologies, systems and concepts on user coaching with IT, e-health monitoring and coaching and applications of VR in health coaching will be reviewed.

2.1.1 Chatbots

The earliest concepts of interacting with a user and answering questions lead to chatbots. Chatbots are computer systems that allow a conversation with humans by textual or auditory methods using natural language dialogues. The technology of chatbots was introduced in 1966 with ELIZA. This chatbot made users think that they were interacting with a real human. Chatbots like ELIZA could not keep conversations going because it used keyword matching and minimal context identification. Once ELIZA recognized a keyword, it changed the sentence to match the keyword according to the rules in a script. The earliest chatbots were designed to have a simple conversation or for entertainment. Since the introduction of chatbots in human-computer-interaction and development of other technologies, chatbots have become very dynamic. There are different ways

these chatbots operate and can be categorized. Modern chatbots use Artificial Intelligence to answer the complex questions but the currently used chatbots still have difficulties with having coherent, contextual and natural conversations [11]. Chatbots can be classified in the following categories: Interaction Mode, Chatbot Application, Rule-based or AI and Domain-Specific or Open-Domain. Chatbots that use a voice-based interaction mode and are task-oriented, are, for example, Alexa and Siri. They help the user to achieve certain tasks. Non-task-oriented chatbots are designed to recreate the human to human text-based conversation and do not have a specific goal. Chatbots like these fall into the generative-based or retrieval-based category. They try to generate proper answers during the conversation and try to select answers to the current conversation from a repository. ELIZA is an example of this type of chatbot. The use of natural language is seen as an important opportunity in personalising interaction by allowing users to have a conversation with the application in their way. It gives more freedom to the interaction because the interaction is not stuck to certain pre-sets. Analysing and dealing with the user input is done using different strategies or algorithms to generate a proper answer to the user. The easiest type of chatbots are dialogue systems like ELIZA, but with the new developments in machine learning and artificial intelligence, the chatbots can become smart, intelligent and autonomous agents [12].

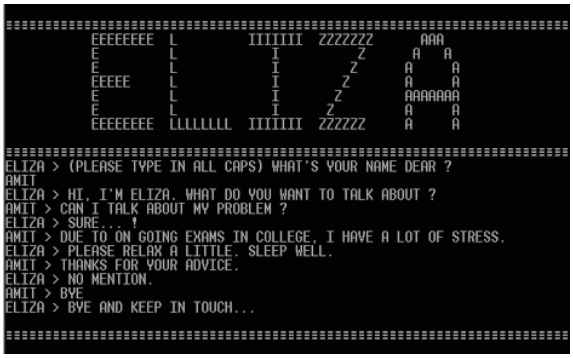

Figure 3: Chatbot ELIZA [11]

Figure 4: Voice-based chatbot Siri [12]

2.1.2 Multi-agent

The use of single agents has become important in customer service, learning, gaming and healthcare. Social virtual agents are being used in different healthcare applications to provide assistance, coaching and explanation. Most of these interactions are between a user and a single agent. There has been a rise in the use of multiparty conversations, the use of multiple agents with different roles. This has shown to cause longer interaction by sending more messages [13]. Next to that, the agents can replace and react to other agents which leads to a smooth conversation [13]. The agents use nonverbal signals, lexical and semantic information to do this. Council of Coaches uses multiple healthcare agents with different domain expertise to coach users [13].

2.1.2.1 High Council Civilization

The concept of coaching users by agents with different domain expertise was first seen in the video game Civilisation 2 from 1996. The High Council of advisors advises to players for strategic decisions about future moves. The High Council consists of expert in the domain of military, science, trade, foreign and attitude. The different agents use their domain to inform the player and in this allow the player to view the strategies from different domains [14].

Figure 5: The High Council in Civilization 2 [14]

2.1.2.2 Inside Out

Another related concept, that uses agents with different domain expertise, is the film Inside Out release in 2015. Riley moves to San Francisco, feels insecure and bumps against her parents who do not understand her behaviour. But then is there her inside, where different personified emotions try to give the best reaction to incentives from outside and accompany a compelling adventure. The emotions Joy, Fear, Anger, Disgust and Sadness conflict on the best way to move to a new city, house and school. Inside Out won an Oscar for 'Best Animated Feature Film' and for 'Best Original Scenario' in 2016 [15].

Figure 6: Inside Out [15]

2.1.2.3 Dilemma

Another concept that uses multi-agent conversation is Dilemma from TXchange. TXchange is a simulation game developer that focuses on improving organisations and people. They believe that developing leadership skills require awareness about how employees gather, judge and use information to deal with difficult situations. With their simulations they allow employees to experiment with the process of judgment and decision-making. Dilemma is a simulation game where the decision making process is simulated in a narrative way. The employee is confronted with different dilemmas and the choices made affect the story in real time. This simulation enables employees to become self-aware in the decision making process and enables them to change and learn. When they finish the simulation, they receive feedback on their decisions [16].

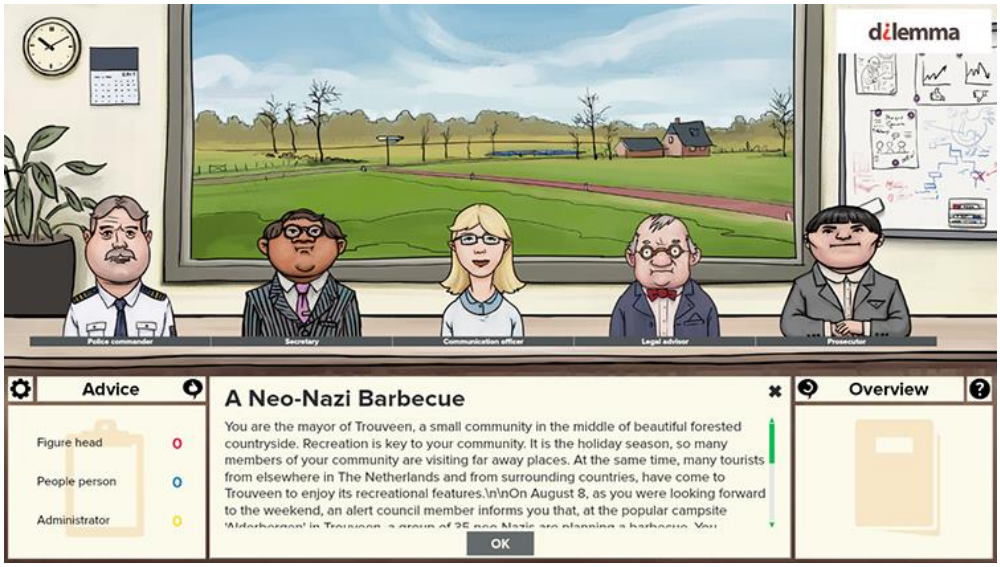

Figure 7: Dilemma [16]

2.1.3 Embodied Conversational Agents

Next to the multi-agent aspect of COUCH, another aspect that is applied in COUCH is the use of Embodied Conversational Agents (ECAs). ECAs are "computer-generated cartoonlike characters that demonstrate many of the same properties as humans in face-to-face conversation, including the ability to produce and respond to verbal and nonverbal communication" [17, p.8]. These ECAs have an interface that is quite similar to the human conversation. ECAs aim to be similar in speech, facial display, hand gestures and body stance [18]. They try to represent the computer in a human way and try to have conversations that look like and progress in a human-like way. The use of ECAs allows the interaction to play an intrinsic role [18]. In the COUCH project, the ECAs Greta and Asap are used. The can be seen in figure 8 below.

Figure 8: ASAP (men) and GRETA (women) ECAs in one scene

2.1.3.1 NEON

The development of ECAs is focused on making the interface and interaction with virtual agents as humane as possible. Samsung Technology and Research Labs (STAR Labs) [19] introduced their new virtual agents, called NEONS, at CES 2020. The virtual agents use artificial intelligence to resemble human emotions and intelligence [19]. This new development shows that ECAs start to look and conversate more and more realistic [19].

Figure 9: Examples of generated Virtual Humans called NEONS [19]

2.1.4 eHealth applications

eHealth is a term for information and communication technologies that try to screen, assess, monitor or promote health, physical activity or social support [20]. The ECAs of COUCH will listen to, inform, help and motivate the user to set and pursue goals to improve their health. COUCH focuses on health and wellbeing related issues, including physical, social, cognitive and mental support. So the system of COUCH is an eHealth application. Examples of related eHealth applications are My Fitness Pal[1], Lifesum[2], Strava[3], Runkeeper[4], Calm[5], Moodfit[6] and Lumosity[7]. eHealth apps like Strava and Runkeeper track the user's physical activity and give an overview of their progress and give tips to improve. Apps like My Fitness

[1] MyFitnessPal, *Myfitnesspal.com*, 2020. [Online]. Available: https://www.myfitnesspal.com/. [Accessed: 19- Apr- 2020]
[2] Lifesum, *Lifesum.com*, 2020. [Online]. Available: https://lifesum.com/. [Accessed: 19- Apr- 2020]
[3] Strava, *Strava.com*, 2020. [Online]. Available: https://www.strava.com/about. [Accessed: 23- Apr- 2020]
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[5] Calm, *Calm.com*, 2020. [Online]. Available: https://www.calm.com/. [Accessed: 19- Apr- 2020]
[6] Moodfit, *Getmoodfit.com*, 2020. [Online]. Available: https://www.getmoodfit.com/. [Accessed: 19- Apr- 2020]
[7] Lumosity, *Lumosity.com*, 2020. [Online]. Available: https://www.lumosity.com/en/. [Accessed: 19- Apr- 2020]

Pal and Lifesum monitor the user's nutrition and give recommendations for recipes or offer plans for weight loss. Apps like Calm help with sleep, stress and meditation. Apps like Moodfit help with depression, stress or social anxieties. Apps like Lumosity give cognitive training on memory and focus. This enumeration of e-health apps is only a small representation of all the different applications. COUCH tries to integrate some of the different domains eHealth applications.

2.1.5 VR coaching applications

There are also health applications available that use the VR technology that allows the user to experience or train health and wellbeing related issues, including physical, social, cognitive and mental support.

2.1.5.1 Embodied Labs

An example of such an application is the Embodied Labs immersive training platform [20]. This platform offers the user a virtual experience of problems and situations facing older adults and their caregivers. This enables the user to gain experience on what it is like to have a disease or an impairment, understand the disease from a first-person perspective, improve teamwork and communication skills and to achieve more interest in working in healthcare or helping older adults [20]. Examples of VR experiences on their platform are The Dima Lab, The Clay Lab, Clay Skills lab, The Beatriz Lab, The Alfred Lab. Respectively, these VR experiences are focused on recognizing, identifying and helping caregivers or older adults on Lewy Body Dementia & Parkinson's Disease, Receiving End of Life Conversations, Giving End of Live Conversations, Alzheimer's Disease, macular degeneration and hearing loss [21].

Research [20] on the platform of Embodied Labs showed that new technology is changing the way the healthcare and aging care workforce are being trained by using the platform from Embodied Labs. Embodying a person living with Alzheimer's disease can positively change behavior and this can result in enhanced person-centered care. Students increased their knowledge, had greater awareness, became more empathic for older adults and ageism bias [20].

The Clay Lab is the experience on the Embodied Labs to experience End of Life Conversations. Below are screenshots of the interaction and experience.

Figure 10: Experiencing an End of Life Conversations with the Embodied Labs platform [20]

2.1.6 Conclusion on Related Work

This section was aimed to create an overview of the existing projects and products that are related to this project. It showed the development of chatbots, multi-agent systems, ECAs, eHealth applications and VR coaching applications for older adults. This section demonstrated that there are some technologies and concepts that preceded COUCH but that there are no comparable systems, especially not in VR. The concept of COUCH is unique because of the multiagent, autonomous and integration approach. This section taught that VR applications can contribute to change behaviour, enhanced person-centred care, more knowledge, awareness and empathy.

2.2 Literature

This section will give an overview of relevant literature for this project.

2.2.1 Virtual Reality for older adults

As already stated in the introduction research has shown that VR is an effective way to teach physical health and it has a positive impact on the doctors and the users [8]. VR technology offers new opportunities and helps the patient' experience of treatments [9]. It can help release stress by allowing the user to experience the real-life experience in a virtual simulation [9]. VR can give a better perception of the surrounding environment, allows for immersion into situations and can resemble virtual motion and experience to the human brain [9].

Improving quality of life

While there were several concerns regarding the use of VR for the older adults at first, VR has indicated its utility in improving elderly people's

quality of life [21}. VR solutions can strengthen the ability to communicate, the social position and the group inclusion of older adults. Owing to its high flexibility, virtual reality can be tailored to various needs and circumstances, thus, it is a viable choice to meet the needs of the elderly [21].

In the diagnosis and recovery of multiple health conditions, VR has had positive results. VR is not an alternative to direct social contact among older adults but instead provides the ability to communicate in a virtual world with other older people that they are not able to meet face to face. To be able to use it in the best way in clinical practice, health practitioners need to understand the impact, benefits, advantages and disadvantages of using VR for older people [21].

One of the applications of VR in elderly people is to assist in the assessment and recovery of cognitive disorders, particularly memory impairment, which can cause many problems for the elderly. VR has been used in various fields such as orientation and navigation, facial recognition, cognitive processing, and other everyday tasks as well and the findings indicate it is useful for them [21]. In older people, VR may also be used in balancing recovery to help them avoid falls, which is a common problem among them because almost 30 per cent of them fall at least once a year [21]. VR technology helps to discover the causes of the falls by simulating the various conditions that trigger the elderly, as well as conducting several experiments in a healthy and simulated environment [21]. Then, it attempts to solve the established triggers by using various simulated situations and performing a variety of exercises and to improve their ability to cope in the real world.

In addition to the above, one of VR's most relevant applications is to enhance the quality of life for older adults through sports, exercises and recreational activities in a healthy and virtual environment, since they deal with certain physical and mental disabilities, they have problems with their social relationships which can lead to loneliness. Although recreational activities are vital to maintaining good health at an early age, VR as an alternative approach will help older people do recreational activities indoors without worrying about external constraints or weather. In reality, they will be able to travel to different places in the world by using VR while enjoying

the comfort of their homes and combining physical activity with tourism-recreation [21].

Teaching and offering practical knowledge and support, strengthening their ability to learn new things. VR can have the advantage of regulating the type and amount of training each patient receives, which can improve the transition of learning to the chosen goals of the user. VR also has the potential to alter current situations by modifying physics and other real-life aspects. Virtual activities may be programmed to regularly learn and practice new skills according to the needs of older adults. The interactive aspect of these treatments can also deliver implicit mechanisms of learning without the patient being aware of them. Using VR and serious games for older adults is commonly classified to strengthen the movements of the upper and lower limbs, coordination, agility training, cognition and balance and training is normally recommended to help reach the daily activities in the older population [22].

Barriers of VR

It should be noted that, when using this technology, preventive measures such as doing so in a safe environment and performing shorter sessions at first should be considered. There are some barriers to the use of VR. These are being costly (1), not widely and easily available (2), low experience in use of VR (3), need for preparation (4), resistance and rejection by the elderly (5), as well as fear and negative attitude of the elderly in the virtual world (6) and technology that should be researched and carefully considered in the first place to achieve the best results (7) [21]. Soltani [19] argued that they need to improve their VR task to solve usability problems. He attributed the poorer elderly results in VR to the problems that elderly people have with using the mouse and likely eye problems from wearing the 3D glasses. The senior population, in general, suffers from technical illiteracy [22]. VR systems should adopt a user-centric approach for optimum effectiveness, and their primary emphasis should be inclusive approach, usability and accessibility [22]. The most important improvements occur when people are faced with the circumstances that cause them anxiety and learn specifically how to think,

feel and act more constructively [24]. That means leaving the meeting room and heading into the real world, with the therapist behaving even more like a personal trainer or leadership coach [24].

2.2.2 Older adults and COUCH

Since COUCH made progress in development, analysis on user and stakeholders have been done. In [25] they found the initial results of the stakeholder interviews and a stakeholder engagement session. They conducted three interviews with a psychologist, policy maker and first-mover in the mHealth domain. The psychologist was an expert in health coaching and the policy maker had technical expertise. The psychologist required that the system shows the support to the user before pushing a healthier lifestyle on the user and the system should not clash with the independence of the user, other options to reach a healthier lifestyle should still be available. The policymaker was also disturbed about the dependence of the user and the addicting effect of the technology and that the user uses its own intuitions and judgement. The policymaker mentioned the importance of the certification, the representation of the user in this process and a description of privacy and use of data. The first-mover thinks that COUCH has a potential in remote areas where there is more difficult access to health care due to time and distance issues. The stakeholder mention that reminders can become annoying and states that a reflection towards users should be positive. Next to interviews, a workshop was conducted. The main conclusions from the workshop were that COUCH should detect the level of motivation and adjust the coaching, always make the user feel positive, use data in a transparent way, be aware that some social groups can be forgotten, focus on the user's needs and make sure it becomes an educating tool that prevents people from becoming dumber or uncritical. They did interviews with three people from the target group that suffer from chronic pain or age-related impairments. Coaches that should be included in COUCH, according to the three users, were a physical therapy coach, a community nurse coach and a doctor. A psychosocial coach or peer were also mentioned but depended on the condition. The stakeholder interviews have taught us that the Council of Coaches technology can and should fulfil

the following tasks: Health education, providing reminders, motivating clients to adhere to medication or training regimes, social support, and health monitoring [21].

2.2.3 Conclusion on Literature

This section was aimed to create an overview of the relevant literature for this project. It showed the benefits of VR: improving the quality of life of older adults, allows needs and circumstances to be tailored to older adults, positive results on medical health, assistance in recovery of cognitive disorders, balancing recovery, enhance health despite physical and mental disabilities, improve social relationships, no external constraints like weather, allow older adults to travel in VR, teach and offer practical knowledge, personal regulating of training intensity, unconscious learning mechanisms, train lower limbs, coordination, agility training, cognition and balance and help reach the daily recommended activities for the older population. Next to the benefits, barriers towards VR were found. These barriers are being costly (1), not widely and easily available (2), low experience in use of VR (3), need for preparation (4), resistance and rejection by the elderly (5), as well as fear and negative attitude of the elderly in the virtual world (6), technology that should be researched and carefully considered in the first place to achieve the best results (7), problems that elderly people have with using the mouse and likely eye problems from wearing the 3D glasses (8) and the fact the senior population, in general, suffers from technical illiteracy (9). Finally the relation between COUCH and older adults was researched. It showed that the Council of Coaches technology can and should fulfil the following tasks: Health education, providing reminders, motivating clients to adhere to medication or training regimes, social support, and health monitoring. The stakeholders argued the importance of independence, supporting, transparency, positivity in the features in COUCH.

2.3 Conclusion and discussion

The goal of this chapter was to give an overview of the existing projects and products that are related to this project and to give an overview of relevant literature for this project and how this literature can be used in the project.

In this section the goal was to answer the following sub research questions.

- What are the factors influencing the engagement of older adults with Virtual Reality?
- What are the factors influencing the engagement of older adults with the Council of Coaches system?

After reviewing the related work and literature it is clear that there is a significant opportunity for the application of COUCH in VR. The related work showed the development of chatbots, multi-agent systems, ECAs, eHealth applications and VR coaching applications for older adults. This section demonstrated that there are some technologies and concepts that preceded COUCH but that there are no comparable systems, especially not in VR. The concept of COUCH is unique because of the multiagent, autonomous and integration approach. This section taught that VR applications can contribute to change behaviour, enhanced person-centred care, more knowledge, awareness and empathy.

The literature showed the benefits of VR: improving the quality of life of older adults, allows needs and circumstances to be tailored to older adults, positive results on medical health, assistance in recovery of cognitive disorders, balancing recovery, enhance health despite physical and mental disabilities, improve social relationships, no external constraints like weather, allow older adults to travel in VR, teach and offer practical knowledge, personal regulating of training intensity, unconscious learning mechanisms, train lower limbs, coordination, agility training, cognition and balance and help reach the daily recommended activities for the older population. Next to the benefits, barriers towards VR were found. These barriers are being costly (1), not widely and easily available (2), low experience in use of VR (3), need for preparation (4), resistance and rejection by the elderly (5), as well as fear and negative attitude of the elderly in the virtual world (6), technology that should be researched and carefully considered in the first place to achieve the best results (7), problems that elderly people have with using the mouse and likely eye problems from wearing the 3D glasses (8) and the fact the senior population, in general, suffers from technical illiteracy (9). Finally the relation between

COUCH and older adults was researched. It showed that the Council of Coaches technology can and should fulfil the following tasks: Health education, providing reminders, motivating clients to adhere to medication or training regimes, social support, and health monitoring. The stakeholders argued the importance of independence, supporting, transparency, positivity in the features in COUCH.

Considering the screen-based interaction version of COUCH and the potential benefits of VR on the human-computer interaction of COUCH, it is interesting to integrate and improve the Council of Coaches system in VR with the target group of older adults in mind.

3 Methods and Techniques

This section will describe structure of the project. This structure is based on the Creative Technology Design Process (CTDP) [26]. Next to that, this section will conclude with an outline to describe the next chapters of the report.

3.1 The Creative Technology Design Process

CTDP is used in the Creative Technology (CreaTe) bachelor programme at the University of Twente. The goal of CreaTe is to design " design products and applications that improve the quality of daily life in its manifold aspects, building on Information and Communication Technology (ICT) [26, p.1]."

The CTDP design method is a balanced combination of Divergence-Convergence and Spiral models of design practice. The Divergence phase is where multiple ideas are generated for the explored subject, while in the Convergence phase the ideas are tightened down to one invention. The Spiral model allows for iterative design process but not iterative steps in a specific order.

The CTDP consists of four phases: ideation, specification, realisation and evaluation. The CTDP is shown in Fig.11. In the ideation phase multiple ideas are generated and designed. In the specification phase, requirements are set and the best design concepts is specified. In the realisation phase, the actual concept is designed according to the requirements. In the evaluation phase, the design gets tested and evaluated.

3.2 Design process for this project

In the ideation phase VR concepts for COUCH will be explored. The chapter starts with a review of the scientific literature on VR design. The requirements learned from the user needs analysis and literature will be used for the design of multiple concepts. These concepts will be presented to users to do a user needs analysis. In the specification phase the designed concepts will be reviewed and prototype testing will be done to come up with the best design concept and to specify requirements for improvement. In the realisation phase the different design methods are explained, the final

concepts and implementation of the final concepts is described. In the final phase, evaluation, the final concepts are evaluated with users. The method, procedure and results of evaluating will be described.

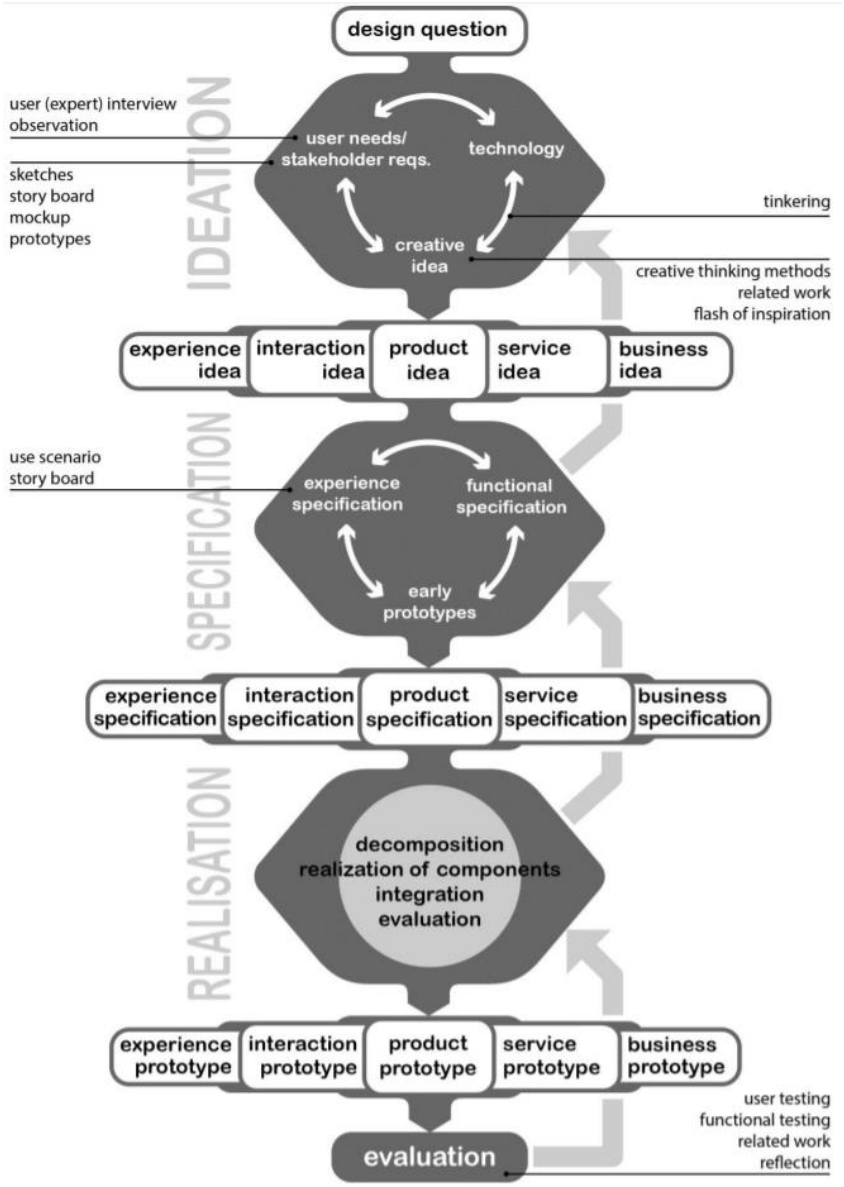


Figure 11: The Creative Technology Design Process [26]

4 Ideation

VR concepts for COUCH will be explored in this chapter. The chapter starts with a review of the scientific literature on VR design. Different concepts will be described and these concepts will be presented to users. The focus of this chapter is to help answer the sub-research question: What factors of the 3D environment are influencing the engagement of older adults with the Council of Coaches system in Virtual Reality?

4.1 Literature on design in VR

In chapter 2 it was shown that related work and research has been done in VR. This section will look into prior VR design research and projects and what can be learned for the design of concepts for COUCH in VR.

The success with which an immersive digital environment can actually immerse the user is dependent on many factors such as believable 3D computer graphics, surround sound, interactive user-input and other factors such as simplicity, functionality and potential for enjoyment [27]. New technologies are currently under development which claim to bring realistic environmental effects to the players' environment – effects like wind, seat vibration and ambient lighting [27].

The research from Kopec et al. [27] showed that older adults were comfortable with the controllers and had fun with the VR headset. They experienced the stationary (seated) and room scale (some movement around) as novel experiences. They agreed that room-scale experiences were more impressive and polished. Common suggestion from the participants was to start using VR when sitting down, to avoid the danger of bumping into real things or leaning against virtual objects.

They found that granting older adults access to technology, which may otherwise be out of their reach is a very good way to guarantee engagement, and usually it is enough to convince them to participate in the development process. Additionally, the whole team and the users alike need to feel that their insights are appreciated and valued, so it is key to schedule the meetings with enough time for digression and extensive questions about the technology or the project itself.

Overall, the participants noticed that immersion is fuller when using the stationary VR headset. This is contrast with the above mentioned more impressive and polished room-scale experiences. The fuller immersion is mainly caused because of the more comfortable stationary experience. Considering the user group, older adults, and their possible weaker physical condition, it would be useful to aim for a stationary experience for this project. In terms of interactivity, they were divided - as half of them preferred selecting options with a gaze pointer solution, while the others preferred to use controllers.

McGlynn and Rogers [28] researched design recommendations to enhance Virtual Reality presence for older adults. They stated that primary considerations for enhancing VR experiences are the level of immersion enabled by the technology and the level of presence experienced by the user. Older adults are often overlooked during the design and application of VR technologies, even though these types of systems may help overcome certain aspects of the age-related challenges and limitations that they experience. The goal of their research was to provide an overview of the applications of VR for older adults and to identify characteristics of older users that could impact the way they experience these advanced technologies. The design recommendations for increasing the likelihood that the immersiveness of the VR system has its intended effect on the experience of virtual presence for older adults that they found are shown in Fig. 12.

In context to this project there are some recommendations from McGlynn and Rogers that can be used in the VR environment design process. Recommendations like using seated virtual experience when possible, increase contrast ratios, block out irrelevant physical stimuli, avoid use of high frequency tones for feedback and 3D localization, increase signal/noise ratio of virtual environment by removing stimuli that are non-task critical, increase positively-valenced stimuli for items to be attended to and increase positively-valenced emotional content.

Domain	Age-related considerations	Design Recommendation
Physical	Musculoskeletal fatigue and discomfort, balance issues	- Reduce HMD weight - Opt for gesture-based controller when possible - Opt for seated virtual experiences when possible
	Visual detection thresholds, glare sensitivity	- Increase contrast ratios and illumination - Block out irrelevant physical stimuli (e.g., glare)
	Auditory detection thresholds, localization	- Avoid use of high frequency tones for feedback and 3D localization
	Haptic vibration detection thresholds (relatively well-preserved)	- Opt for tactile feedback where possible (but increase vibration intensity) - Consider trade-offs of physical controller (increased presence-reducing fatigue) vs. gesture controls (reduced presence-inducing feedback)
Cognitive	Attentional inhibition deficits, divided attention deficits	- Increase signal/noise ratio of virtual environment by removing stimuli that are non-task-critical - Increase positively-valenced stimuli for items needed to be attended to
	Source memory declines	- Avoid memory-based presence measurements - Increase positively-valenced feedback for controls needed to be memorized
Emotional	Positivity bias	- Increase positively-valenced emotional content and sensory feedback

Figure 12: Design recommendations for VR design [28]

4.2 User scenario

Ms. Williams is a retired nurse who is dealing with weight problems due to the wrong diet and lack of physical activity. For the last few months she had weekly appointments with her general practitioner, diet coach and personal trainer to discuss her health, nutrition and physical activity. Ms. Williams really wants to reach her goals and is interested in the latest methods and assistive technologies to help her reach her goals. Her general practitioner introduced her with a new application, the Council of Coaches. This allows her to discuss her health, nutrition and physical activity in an integrated way and at her own place. Ms. Williams has been using the Council of Coaches system for the last weeks but realizes she misses the face-to-face, in person, experience. She scheduled a meeting to discuss this issue with her general practitioner, the general practitioner told her about the system in Virtual Reality and she decides to try the Council of Coaches system in VR. Ms. Williams borrows a VR headset from her grandson with the installed COUCH application. She takes a seat, puts on the headset, starts the headset and runs the application. The coaches appear in front of her in an empty room, apart from the coaches and chairs (like in Fig. 8). She has a discussion about her health, nutrition and physical activity with those coaches. After the discussion she turns off the headset and is back in her own living room. She decides to schedule a new appointment with her general practitioner. On the one hand, she did have a feeling of experiencing a more face-to-face discussion because of the switch from screen based to VR interaction with the ECAs. On the other hand, the flawed environment disables her to have the same goal-reaching experience as with the in person coach meetings. The general practitioner and Ms. Williams discuss that a new modelled environment might help in her experience.

The scenario is a description of the hypothetical use of the COUCH system and showed that an new modelled environment could improve the experience of Ms. Williams. This use issue can be used in the (re-)design of the system.

4.3 Personas

Personas, that describe different types of user groups and their preferred environment, are used to describe and understand what possible concept environments can be used in the design process.

Peter is a fifty-five year old man who has a physical job and lives in a remote area. He uses the COUCH system only to save travel time and receive direct feedback on his physical problems. He needs the system for the functional aspects of it and would like an environment that resembles normal meeting environments. The focus of Peter is on the functional, realistic aspect of the environment,

Kate is a sixty year old teacher who does not have any physical, cognitive, mental or social problems. She is interested in the possibilities of new technologies and wants to learn about health and lifestyle. For her it is important that she experiences the possibilities of the new VR technology. She wants the environment to be extraordinary to improve her own experience.

John is a fifty-two year old man who just lost his job. He had a burnout and lost his job which caused mental problems. He uses the COUCH meetings to help him with his daily struggles and to calm down from the daily affairs. He would like an environment that helps him release stress and inspires him to work on his mental problems.

These personas describe three different types of potential users. Users who need it for feedback on their progress, want to learn new things or who need it to help them with and distract them from their problems. These personas help in the ideation on different categories of environments. The different categories are realistic & practical, extraordinary & impressive and natural and inspiring.

4.4 Different concepts

The literature, scenario and personas helped with understanding the potential users and design factors. Based on the personas three different environment categories were identified. These categories were used in a brainstorm session to ideate on different concepts. The concepts of the forest and beach fall into the natural and inspiring category. The general

practitioner office and living room fall in the realistic & practical category and the concepts of the space center and garden fall in the extraordinary & impressive category.

These concepts are displayed in this section and an explanation for these concepts are described. These concepts will be used in the user confrontation to find the preference of the user and use their feedback.

The goal of these environments is to increase the engagement of the user by improving the COUCH experience in VR. These environments contribute to this by making the experience more realistic, impressive or calming.

Forest

Figure 13: Pictures representing the "forest" concept [25 and 26]

The forest is an environment where people go to calm down, enjoy nature or have a conversation while having a peaceful walk. This is an environment that is particularly suitable for the potential users that want to work on their problems or discuss their health in a natural and inspiring environment.

Beach

Figure 14: Pictures representing the "beach" concept [27 and 28]

The beach is an environment where people go to calm down, enjoy the sea and view or go for a swim. This is an environment that is particularly suitable for the potential users that want to work on their problems or discuss their health in a natural and inspiring environment that is distant from their daily environment.

General practitioner office

Figure 15: Pictures representing the "general practitioner office" concept [29 and 30]

This environment that most people do not like to visit on a regular basis. It is a place where people go to discuss health problems. This environment could be engaging for potential users that are looking for a recognizable and realistic environment to get feedback.

Living room

Figure 16: Pictures representing the "living room" concept [31 and 32]

This is a place where people have the most conversations with friends, family or guests. It is a good place to discuss health problems in a recognizable and realistic environment. This environment could be engaging for potential users that are looking for a recognizable and realistic environment to get feedback.

Space center

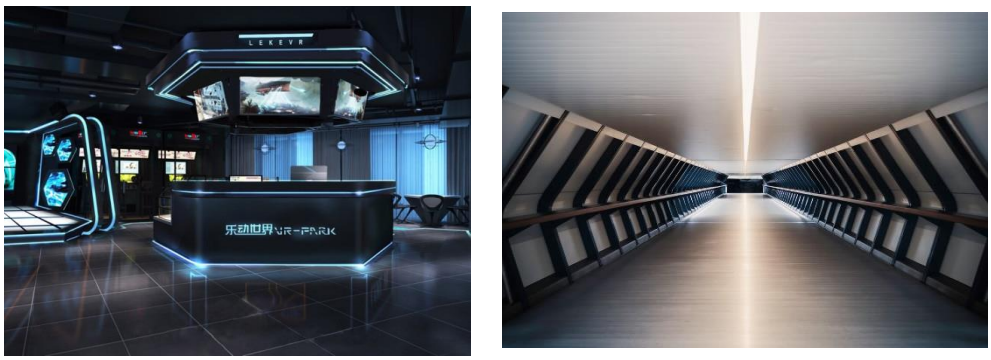


Figure 17: Pictures representing the "space center" concept [33 and 34]

This is an environment that most of the users will never experience or visit in real-life. So it is pre-eminently a place that triggers imagination and allows for new experiences. This is in particular an environment for the user group that is looking for new experiences with VR and who are interested in discovering new knowledge.

Garden

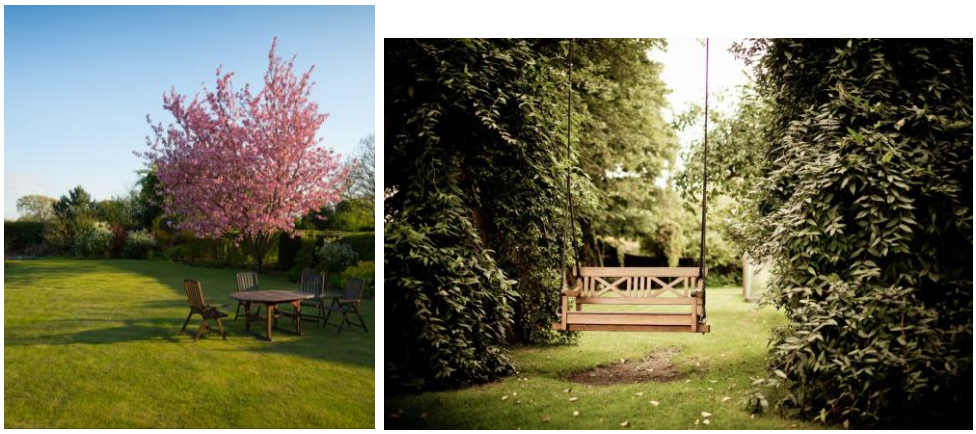


Figure 18: Pictures representing the "garden" concept [35 and 36]

The garden is a place where people go to enjoy the view, nature or to calm down. But next to that, certain types of gardens allow people to experience flower arrangements or fountains. Big gardens with different types of nature, flowers and fountains are a popular place to visit.

4.5 User confrontation

In this section, a user interview will be conducted to involve potential users in the ideation phase. The goal of this user interview is to find out what the opinions are on the different concepts from chapter 4.2, what kind of environment they like, if they prefer sitting or standing during the conversation, if they prefer an indoor or outdoor VR experience and if they have other suggestions for the environment. The findings of this section will be used to specify the concept of the prototype.

4.5.1 Setup

Before conducting the interview, participants receive a short explanation about the research. They receive an information brochure for further details about the research background, procedure, participation, data selection and storage and contact details for more information, independent advice or to file a complaint. They also sign a consent form and receive a copy of the consent form. The information brochure and consent form are attached in, respectively Appendix A and B. For this interview two participants were selected and a laptop, to share a video and multiple pictures, was used during the interview.

4.5.2 Procedure

The interview starts with a short introduction about the concept of COUCH to give the participants an idea about the function, goal and operation of the system. After this, a video of the prototype[8], from 8 January 2020, with all agents will be shown to give the participants an idea about the ECAs, environments and the conversation dialogue. After this introduction of the concept of COUCH, the different concepts from section 4.2 are shown. The participants are asked to imagine that the concepts and environments are in VR. Each different concept is shown and a short explanation is given about the concept. After the concepts are shown, the interview questions will be asked. Each concept on its own will be discussed and some general questions are asked. The interview will be semi-structured. The open

[8] Council of Coaches, *Final Prototype – Coaching content based on sensor data.* Available at: https://www.youtube.com/watch?v=BcS2Hz-w3Rc&pbjreload=101

questions help to collect in-depth information. The detailed interview procedure is included in Appendix C.

4.5.3 Results

The goal of this user interview was to find out what the opinions are on the different concepts from chapter 4.2, what kind of environment they like, if they prefer sitting or standing during the conversation, if they prefer an indoor or outdoor VR experience and if they have other suggestion for the concept. The minutes of the interviews can be found in appendix D.

They interviewed answered some questions that can be used in specification of the concept. The participants mentioned the preference of an environment that is realistic, soothing, gives the feeling of being in nature, does not distract the user from the conversation, has an outside view on a landscape or nature scenery. The concepts of the forest and beach were preferred over the concepts of the office of an general practitioner, living room, space center or garden because of the daylight, view, peaceful location and the feeling of being surrounded by natural aspects.

Both participants preferred that the conversation takes place while sitting down. Participant #2 mentioned walking around would be liked during the conversation but mentioned the technological limitations of VR and preferred sitting over standing.

Both participants preferred that the conversation takes place in an indoor environment. Both mentioned that also in VR privacy/confidentiality plays a role and an indoor environment would help with that. On the other hand, they both mentioned the importance of having a view.

4.5.4 Conclusion on the user confrontation

The user confrontation answered multiple questions about the concepts and different components of the environment in VR. The participants preferred an environment that was indoors, with a view on a landscape that allowed the COUCH conversation to take place while sitting down.

4.6 Conclusion on ideation

The goal of this chapter was to explore different concepts, describe these concepts and show them to potential users. The focus of the chapter was to help answer the sub-research question: What factors of the 3D environment are influencing the engagement of older adults with the Council of Coaches system in Virtual Reality?

Kopec et al. found that the success with which an immersive digital environment can actually immerse the user is dependent on many factors such as believable 3D computer graphics, surround sound, interactive user-input and other factors such as simplicity, functionality and potential for enjoyment. Kopec et al. mentioned that room-scale experiences were more impressive while some contestants of their research and the participants of the user confrontation of 4.3 preferred sitting down.

McGlynn and Rogers [28] researched design recommendations to enhance Virtual Reality presence for older adults. They stated that primary considerations for enhancing VR experiences are the level of immersion enabled by the technology and the level of presence experienced by the user.

In context to this project there are some recommendations that can be used in VR environment design process like using seated virtual experience when possible, increase contrast ratios, block out irrelevant physical stimuli, avoid use of high frequency tones for feedback and 3D localization, increase signal/noise ratio of virtual environment by removing stimuli that are non-task critical.

The participants preferred an environment that was indoors, with a view on a landscape that allowed the COUCH conversation to take place while sitting down.

5 Specification

In the previous chapters different concepts were explored and evaluated. In this section the user requirements and the functional specification development will be described. Both software and hardware systems will be described, along with the final concept.

5.1 Oculus Quest

The COUCH system in VR will be prototyped and evaluated with the Oculus Quest VR headset. The Oculus Quest is the first VR headset that does not need a pc to run. Next to that, the Quest is wireless and enables more options to move. On top of the headset 4 cameras scan the environment and enable six degrees of freedom (6DoF). This 6DoF allows the detection of forward/backward, up/down or left/right movement and the rotation about three perpendicular axis. The Quest recognizes when the user jumps, turns or bends and translates it to the VR application. Next to a headset, the system uses two controllers to control the input from the hand movements and buttons [25]. An application running on the Oculus Quest enables connection with the COUCH system in Unity via Wi-Fi and a USB-C cable,

Figure 19: The Oculus Quest VR headset [25]

5.2 Unity

Unity is a game engine that allows developers to create games for 25 different platforms. In Unity, 2D and 3D games, VR, Augmented Reality, simulations and other experiences can be created. A screenshot of the Unity interface is display in Fig. 20. The system allows developers to control the assets, scripts, game and the creation of animations. Unity enables sharing projects with the Oculus Quest and enables the import of assets from other

design software like Maya which will be used to model components of the environment.

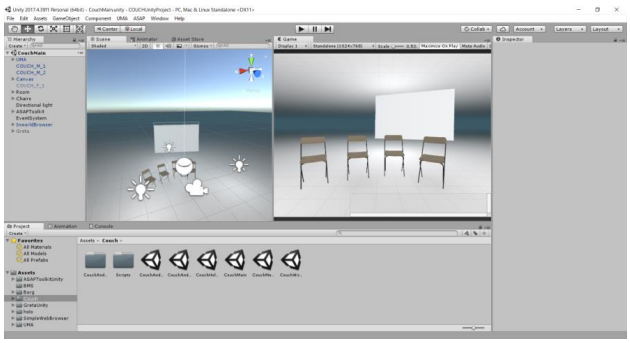


Figure 20: Unity Couch project interface

Maya

Maya is a software from Autodesk for 3D modelling, animations, simulations and rendering. In this project Maya is used to model different assets for the environment in VR. The interface for Maya is shown in Fig. 21. A house, couch, table and chairs will be modelled in Maya. Assets that are created in Maya can easily be exported to the Unity software.

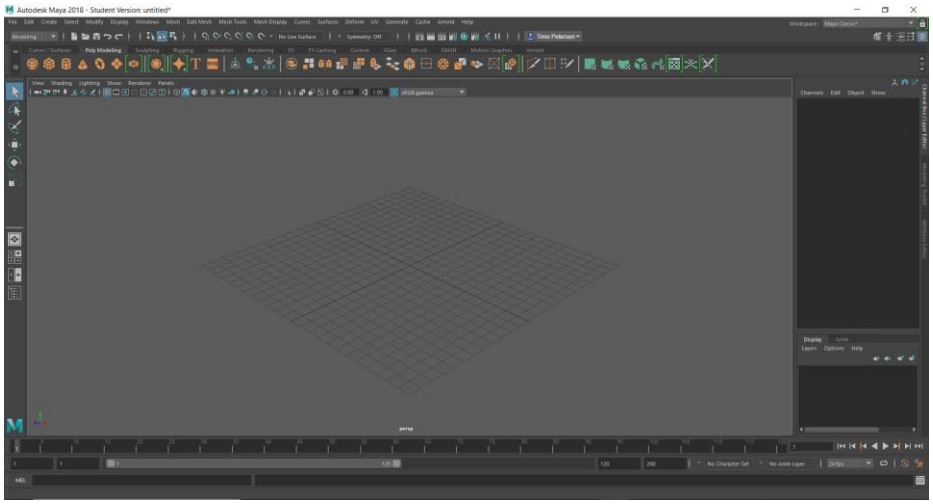


Figure 21: Maya 3D modelling software interface

5.3 Demonstrator

In this project a demonstrator from the COUCH project will be used to run the council meeting with the user. The demo will be downloaded and

installed from GitHub[9]. The Agents United Open Platform is used to build a system of multiple virtual embodied conversational agents. The Agents United platform and the demonstrator are the outcome of the Council of Coaches project. The Agents United platform consists of multiple modules that have their own repository. Some modules are hosted locally and these are:

- DAF: The Dialogue and Argumentation Framework
- HMI Couch: The Conversational Intent Planner
- UnityProject: Unity3D scenes for the agents user interface
- Demonstrator: This repository, which also contains a collection of executable scripts

The universAAL module that connects to the universal IoT platform is hostedin Agents United. Some modules are hosted elsewhere and these are:

- Greta: Socio-emotional virtual characters for agents by ISIR - University of Sorbonne
- HMI Build: Multi-platform build system by HMI - University of Twente
- WOOL Web Service: Knowledge base and dialogue management web service of the WOOL Platform

In this project changes for the demonstrator will be made in the UnityProject and a dialogue game will be written for the conversation between the user and the coaches. In the UnityProject module the Unity3D scenes for the agents user interface will be changed. The modelled environment and the Oculus Integration[10] component, that which allows the development and support for the Oculus Quest, will be added in here. In the conversation, the user and coaches will discuss the user's physical activity

[9] AgentsUnited Demonstrator, github.*com*, 2020. [Online]. Available: https://github.com/AgentsUnited/demonstrator [Accessed: 4- Jun - 2020]

[10] Oculus Integration, assetstore.unity.*com*, 2020. [Online]. Available: https://assetstore.unity.com/publishers/25353 [Accessed: 11- Jun - 2020]

and set goals. This way all participants experience the same coaching experience and this allows the DAF to be a constant variable in the evaluation.

5.4 Description of final concepts

In chapter 4 different concept ideations were developed and evaluated with potential users. The output from the Ideation phase helps to develop an improved description of the final prototype. The participants preferred an environment that was indoors, with a view on a landscape that allowed the COUCH conversation to take place while sitting down. The beach and forest were the preferred environments of the potential users.

In the ideation phase the different components were described and the potential users were confronted with the concepts. For this project the goal is to research how a new 3D modelled environment can influence the engagement of older adults with the Council of Coaches system in Virtual Reality. For the evaluation phase, the different aspects found in Ideation will be used to evaluate the effect on the engagement.

In the Ideation phase the following components that affect the experience were identified:

- Environment
- Stationary vs. room-scale
- Inside vs. outside

In this project, four prototypes will be designed. A screen-based prototype for the beach environment, a VR prototype for the beach environment, screen-based prototype for the forest environment and a VR prototype for the forest environment. For the rest of this report they will be called Beach2D, BeachVR, Forest2D and ForestVR. The composition of different pictures that will be used for the development of the prototypes are shown below. The beach2D and BeachVR environment contains the required components of the outlook on a nature scenery, indoor conversation experience and the preferred concept of the beach. While the Forest2D and

Forest VR environment contains the view on the forest, the outside conversation and the room-scale movement.

Beach2D and BeachVR	**Forest2D and ForestVR**
Beach environment	Forest environment
Inside “beach house”	Open environment
Stationary	Room-scale movement
Table + chairs + couch	No table and different chairs
Beach sound (waves + seagulls)	Forest sound (Birds)

Table 1: Components different prototypes

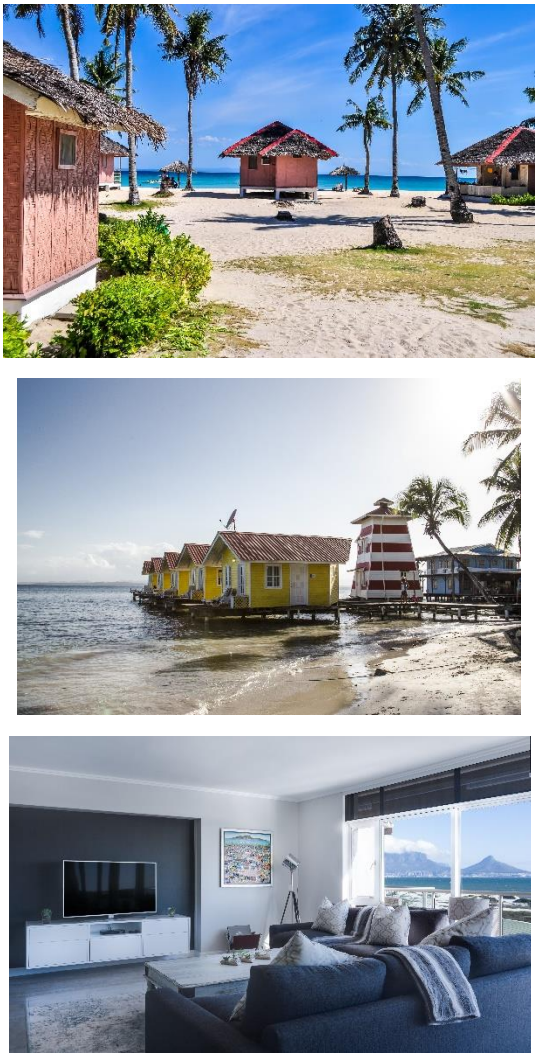


Figure 22: Composition of visualizations for the beach environment [37]

Figure 23: Floorplan for the indoor environment

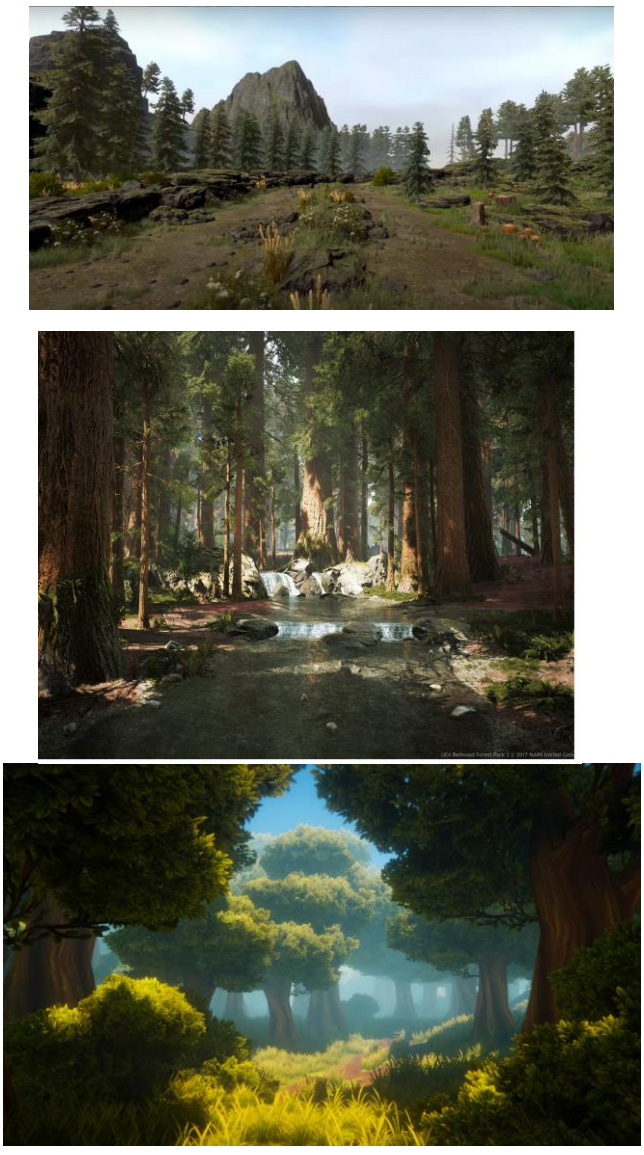


Figure 24: Composition of visualizations for the forest environment [38, 39 and 40]

6 Realisation

In the previous chapters the concepts for the final protypes were described. In this chapter the development of the final prototypes will be described. The use of the demonstrator, the design of the beach and forest environment, the beach house, chairs, table and couch, conversation, interaction mechanism for the VR prototypes, the different sounds and the Unity and Oculus integration will be described.

6.1 Demonstrator

This project is using the technical demonstrator of the COUCH project as a basis. A beach and forest environment, beach house, chairs, table, couch, interaction mechanism for the VR prototypes, different sounds and an Oculus integration will be added to this technical demonstrator. The demo will be downloaded and installed from GitHub[11]. In Figure 25 the demo scene in Unity is shown.

Greta and Asap are platforms that are used for multimodal behaviour generation and for visualising Embodied Conversational Agents (ECA) into the Unity3D engine. In this project the Asap platform will be used so the Greta component will be disabled. The InWorldBrowser allows the use of a browser to show videos or webpages in the technical demonstrator. In this project this component will not be used it is also disabled.

The Canvas, UMA, EventSystem and AsapToolkit from the technical demonstrator will be used. The Canvas controls and displays the dialogue moves for the agents and the user. The UMA component creates the agents and visualizes them, the EventSystem component manages the different events that are happening in the system and the AsapToolkit is used for the multimodal behaviour generation and for visualising Embodied Conversational Agents (ECA) into the Unity3D engine.

[11] AgentsUnited Demonstrator, github.*com*, 2020. [Online]. Available: https://github.com/AgentsUnited/demonstrator [Accessed: 4- Jun - 2020]

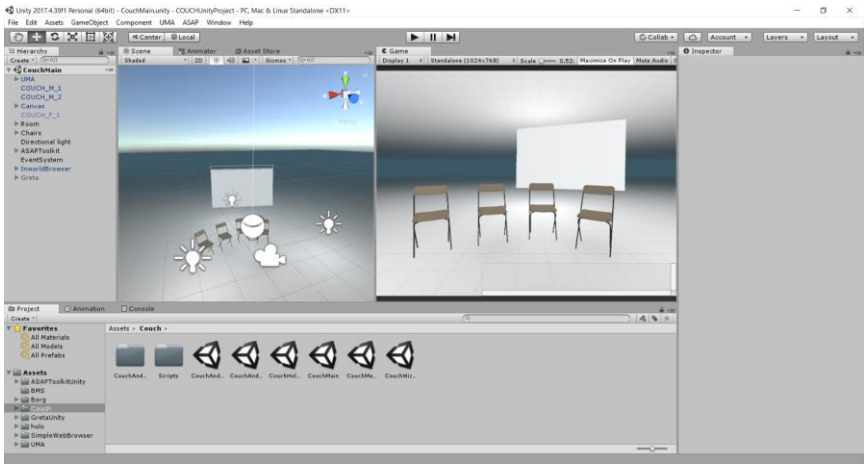


Figure 25: Unity COUCH demo scene

6.2 Beach environment

To create the beach environment, a terrain was created. The Sand texture from the Standard Assets[12] was applied to the terrain and the Water Prefab from the Standard Assets was imported. The Unity tool to Raise/Lower the terrain was used to create the beach as you can see in Fig. 26.

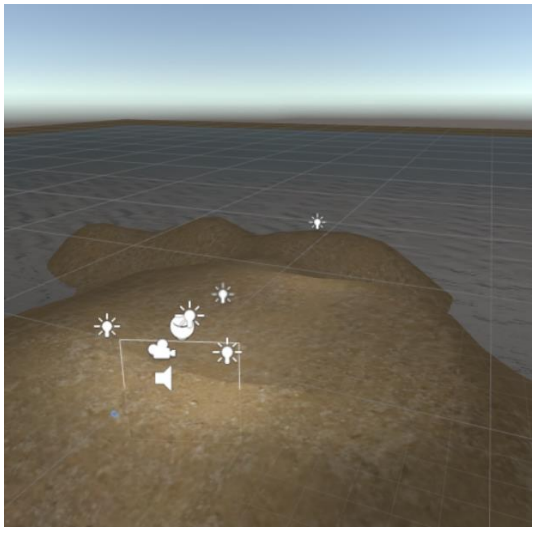


Figure 26: Screenshot of the beach environment

6.2.1 Beach House

The Beach House for the beach environment was modelled in Maya by the researcher and glass window was added in Unity. Figure 22 from chapter

[12] Standard Assets, assetstore.unity.com, 2020. [Online]. Available: https://assetstore.unity.com/packages/essentials/asset-packs/standard-assets-for-unity-2017-3-32351 [Accessed: 4-Jun - 2020]

5.4 was used as example for the modelling. Different wood and colour textures were applied in Unity. The beach house can be seen in Fig. 27.

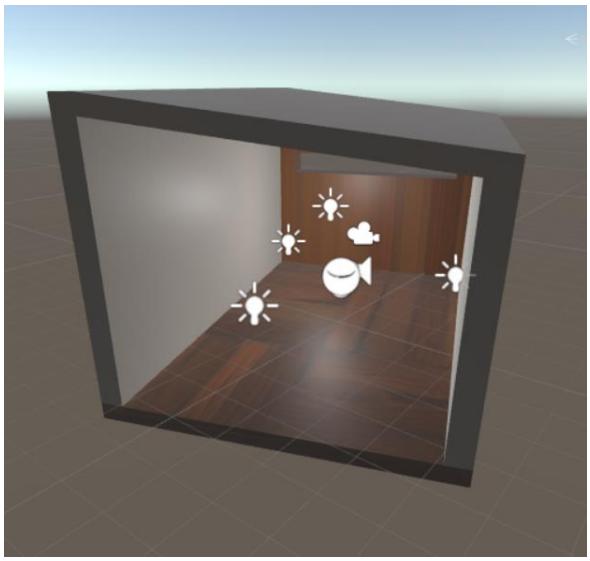


Figure 27: The Beach House model

6.2.2 Couch

The couch model for the beach prototypes was modelled in Maya. The Sofa Modelling in Maya[13] tutorial was followed for the model. The couch can be seen in Fig. 28.

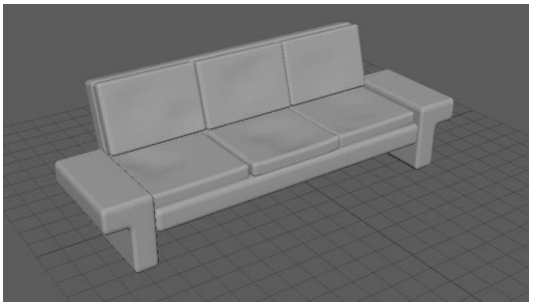


Figure 28: The couch model

6.2.3 Chairs

The chair model for the beach prototypes was modelled in Maya. The How

[13] The Sofa Modelling in Maya, youtube.com, 2020. [Online]. Available: https://www.youtube.com/watch?v=yIGijOsQH30

to Model a Full Dining Table in Maya[14] tutorial was followed for the model. The chairs can be seen in Fig. 29.

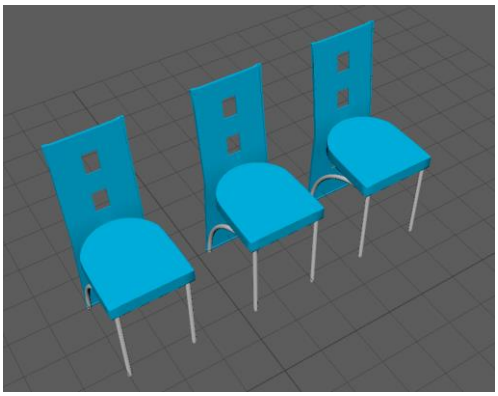


Figure 29: The chair models

6.2.4 Table

The table model for the beach prototypes was modelled in Maya. The How to Model a Full Dining Table in Maya[15] tutorial was followed for the model. The table can be seen in Fig. 30.

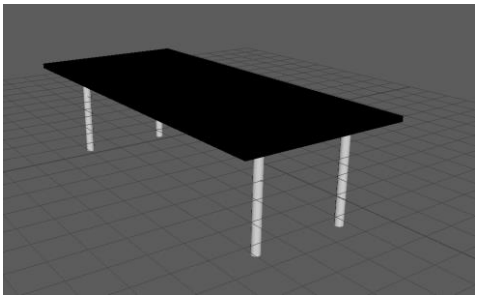


Figure 30: The table model

6.2.5 Integrating components in the Beach environment

To create the beach environment, the beach terrain, beach house, couch, table and chairs were integrated into the technical demonstrator. The beach house, couch, table and chairs that were modelled in Maya can be exported

[14] How to Model a Full Dining Table in Maya, youtube.com, 2020. [Online]. Available: https://www.youtube.com/watch?v=znWrXxnEX6w

[15] How to Model a Full Dining Table in Maya, youtube.com, 2020. [Online]. Available: [15] https://www.youtube.com/watch?v=znWrXxnEX6w

to Unity and integrated as a new asset. The result of the integration of the different components can be seen in Fig. 31.

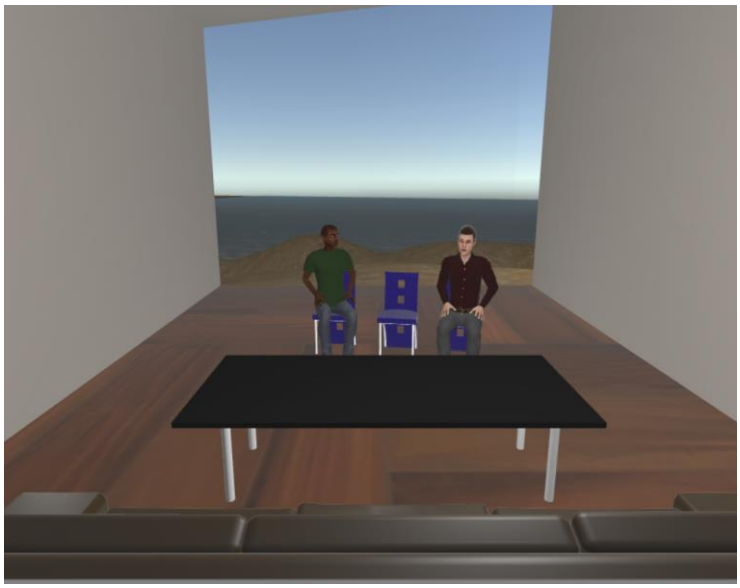


Figure 31: The Beach prototype seen from the user's perspective

6.3 Forest environment

For the forest environment, the demo scene of the Dream Forest Tree[16] Unity package was used. This package has free to use license. Some changes were made in the height of the terrain for a better view on the agents and location of the user in VR. The chairs that are used come from the technical demonstrator that was the basis for this project. The agents are placed on these chairs at the edge of the forest. The forest can be seen in Fig. 32 and the Forest environment in the camera view for the user can be seen in Fig. 33.

[16] Dream Forest Tree, assetstore.unity.com, 2020. [Online]. Available: https://assetstore.unity.com/packages/3d/vegetation/trees/dream-forest-tree-105297 [Accessed: 4- Jun - 2020]

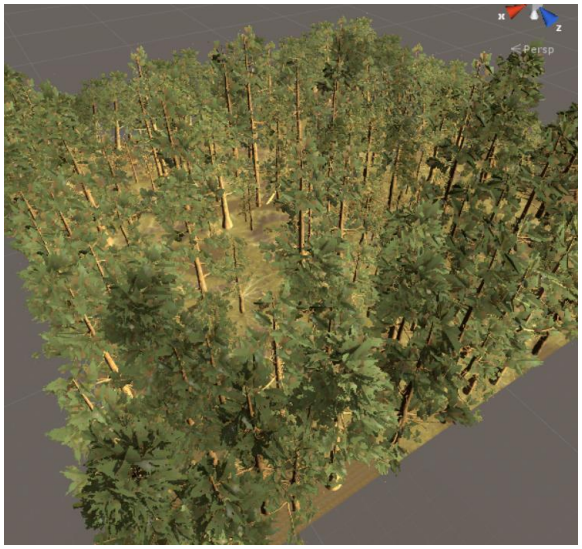


Figure 32: Screenshot of the forest in the Scene manager

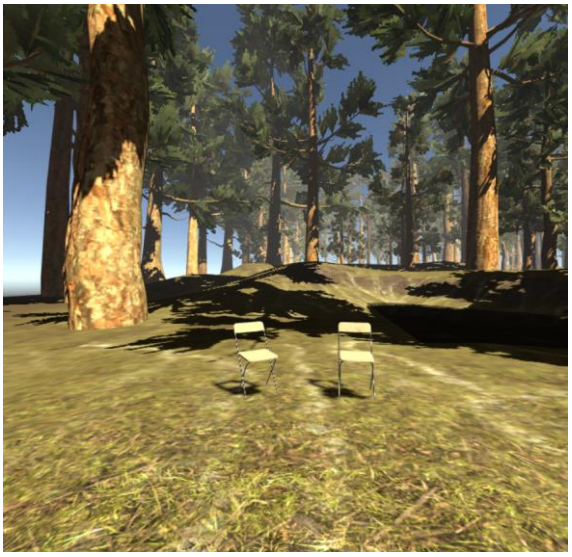


Figure 33: The forest environment in the Camera view

6.4 Conversation

For the conversation between the user and the agents a dialogue game will be written. The Agents United Dialogue and Argumentation Framework Quick Start Guide was used to create a new protocol. In Figure 33, a diagram of the conversation is shown. In this conversation, the user is introduced to the concept of COUCH and what will be discusses in this council meeting, the user will discuss their activity for that day and set a new goal for the rest of the day. The code for this dialogue is attached in Appendix F.

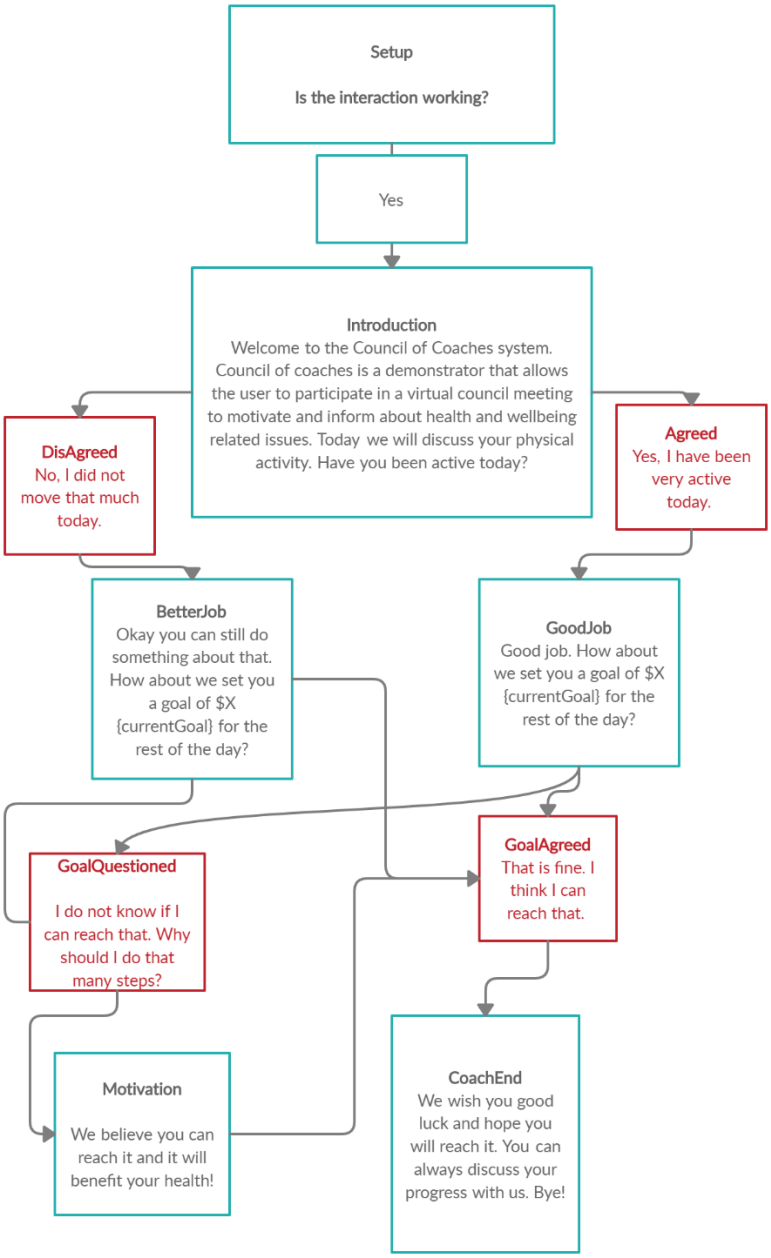


Figure 34: Diagram of the Conversation

6.5 Unity and Oculus Quest

To use the Quest for the BeachVR and ForestVR the Oculus Integration v17.0 was imported into Unity. From this package the OVRPlayerController, OVRCameraRig and OVRGazePointer were integrated in the prototypes. The OVRPlayerController allows Unity to use the Quest input to control the interaction and camera view. The OVRCameraRig allows Unity to use the Quest input to control the camera view. The OVRGazePointer allows Unity to use the input from the Quest to

control a GazePointer, a blue circle, that can interact with buttons with the use of the view of the headset and hand movements.

The Unity Documentation for Oculus Development[17] was used to setup the project and the Quest. The Quest was used to run as an Oculus Rift thanks to the Oculus Link[18] compatibility. This allowed the Unity scene to run on the PC and stream the images to the headset through the USH cable on the Quest.

6.6 Sounds

Sounds of waves and seagulls[19] were added to the Beach2D and BeachVR prototypes. Bird sounds[20] were added to the Forest2D and ForestVR prototypes. The idea of using these sounds is to improve the experience by making it feel and especially sound more realistic. These sounds are free to use and will play all the time while the scene is running.

6.7 Interaction

To select the possible moves for the user in the dialogue, an interaction mechanism had to be designed. In this project the canvas was set to worldspace, resized and placed in front of the agents facing the user. In the Beach2D and BeachVR prototypes the buttons were placed above the table while in the Forest2D and ForestVR the moves were placed in front of the agents. The placement of the buttons can be seen in Fig. 35 and Fig. 36.

[17] Enable Device for Development and Testing

Developer.oculus.com, 2020. [Online]. Available: https://developer.oculus.com/documentation/unity

[18] Setup Quest headset with Link

Developer.oculus.com, 2020. [Online]. Available: https://support.oculus.com/525406631321134/?locale=nl_NL

[19] Klankbeeld, freesound.org, 2020. [Online]. Available: https://freesound.org/people/klankbeeld/sounds/524493/

[20] Suukadi, freesound.org [Online] Available at: https://freesound.org/people/suukadi/sounds/410323/

Figure 35: Interaction in Beach2D and BeachVR

Figure 36: Interaction in Forest2D and ForestVR

For the interaction in Beach2D and Forest2D the Mouse Interaction was used but for the BeachVR and ForestVR a different interaction was needed. In these prototypes a GazePointer was used. The OVRGazePointer allows Unity to use the input from the Quest to control a GazePointer, a blue circle, that can interact with buttons with the use of the view of the headset and hand movements. This GazePointer needed a new EventSystem with the OVR Input Module connected and the GazePoiner prefab. The GazePointer is a blue ring that is controlled by the headset and can select moves with a hand gesture.

Figure 37: GazePointer in BeachVR

6.8 Final Prototypes

This chapter described the process, methods and progress of the final prototypes which are shown in Table 2.

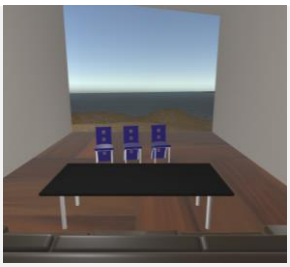
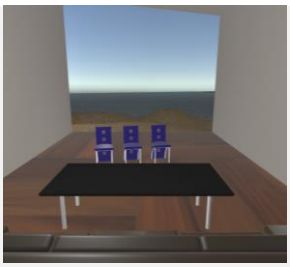
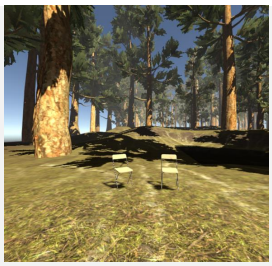
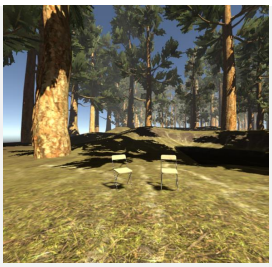
Beach2D	**BeachVR**	**Forest2D**	**ForestVR**
			
Mouse Interaction	GazePointer	Mouse Interaction	GazePointer
Screen-based	Virtual Reality	Screen-based	Virtual Reality
Inside “BeachHouse”	Inside “BeachHouse”	No house, outdoor	No house, outdoor
Couch, table and different chairs	Couch, table and different chairs	No couch, table and standard chairs	No couch, table and standard chairs
Beach Sound	Beach Sound	Forest Sound	Forest Sound
Conversation “Goalsetting”	Conversation “Goalsetting”	Conversation “Goalsetting	Conversation “Goalsetting

Table 2: Final Prototypes

7 Evaluation

In this chapter, user tests will be conducted to evaluate the prototypes. In this chapter the method, execution and results of the evaluation will be described.

7.1 Introduction

As seen in the research questions of this report, there a few aspects of the prototypes that need to be evaluated. The main research question is: How can a new 3D modelled environment influence the engagement of older adults with the Council of Coaches system in Virtual Reality? The difference in engagement between the screen based prototype and VR prototype and the effect of different components in the environment on the engagement will be evaluated in this evaluation.

7.1.1 Setup of evaluation

For the evaluation, three different studies will be conducted. Studies that differ in user groups and prototypes. For each study, the goal, method (participants, materials and procedure) and results will be described. After the results and discussion for each study, an overall discussion will be described where connections between the different studies will be made.

7.1.2 Prototypes

For the evaluation, four different prototypes will be used. The screen-based beach prototype, VR beach prototype, screen-based forest prototype and VR forest prototype will be used. Screen-based means that the prototype will be tested on the computer without the VR integration and experience. In this report, the 4 different prototypes will be called Beach2D, BeachVR, Forest2D and ForestVR. In all prototypes, the researcher served as a Wizard of Oz. In all the prototypes, the researcher will manually disable the moves for the agents and make sure only the moves for the user is visible.

7.1.3 Questionnaire and semi-structured interview

For the three different studies a short questionnaire and a semi-structured interview will be conducted. In the evaluation the User Engagement Scale (UES-SF) is used to analyse the user engagement. The questionnaire is

attached in Appendix D. The researchers have refined the structure for the UES questionnaire and developed a new short from UES-SF. These questionnaires were validated and the researchers offer guidance for adopting UES and UES-SF in other studies, like this evaluation test. The questionnaire that is used in all studies is attached in Appendix E. Next to a short questionnaire, a semi-structured interview will be conducted to receive qualitative data. The questions for the interview for the different studies are attached in Appendix F.

7.2 Description of the three studies

In Table 2, a general overview of the three studies is shown. The research question, method, participants, materials and procedure for each study will be described below the table.

	Study A	Study B	Study C
Research Question	What is the effect of the different components in Beach2D and Forest2D on older adults?	What is the difference in experience between Beach2D & BeachVR and Forest2D and ForestVR?	What is the effect of the different components on the experience between BeachVR and ForestVR?
Participants	Two older adults	Two older adults with a VR headset and three proxy users with a VR headset	Two older adults with a VR headset and three proxy users with a VR headset
Method	Questionnaire and semi-structured interview	Questionnaire and semi-structured interview	Questionnaire and semi-structured interview
Materials	Beach2D Forest2D Questionnaire and semi-structured interview	Beach2D, BeachVR, Forest2D and ForestVR Questionnaire and semi-structured interview	BeachVR and ForestVR Questionnaire and semi-structured interview
Procedure	1. Explanation 2. Informed consent 3. Instruction	1. Explanation 2. Informed consent 3. Instruction	1. Explanation 2. Informed consent 3. Instruction

	4. Test Beach2D 5. Questionnaire and interview questions 6. Test Forest2D 7. Questionnaire and interview questions 8. Interview questions on comparison Beach2D and Forest2D	4. Test Beach2D 5. Questionnaire and interview questions 6. Test BeachVR 7. Questionnaire and interview questions 8. Interview questions on difference screen-based and VR experience (Beach 2D vs. BeachVR or Forest2D vs. ForestVR)	4. Test BeachVR 5. Questionnaire and interview questions 6. Test ForestVR 7. Questionnaire and interview questions 8. Interview questions on comparison BeachVR and ForestVR

Table 3: Overview of Study A, B and C

7.3 Study A

In Study A, older adults will evaluate the Beach2D and Forest2D prototypes.

7.2.1 Research question of Study A

In this study, the research question is: What is the effect of the different components in Beach2D and Forest2D on older adults?

7.2.2 Method

In this study the participants will interact with the screen-based prototype (Beach2D) and the engagement is measured via a short questionnaire and a semi-structured interview. After that, the participants will interact with the other screen-based prototype (Forest2D) and the engagement is measured via a short questionnaire and a semi-structured interview. After both prototypes are shown, some questions will be asked to compare the different prototypes. The different variables are shown in table 2. To counterbalance the study, half of the participants will start with the Beach2D prototype

while the other half of the participants will start with the Forest2D prototype.

Independent variables	Dependent variables
Beach2D	Level of engagement
Forest2D	User experience

Table 4: Study A variables

7.2.3 Participants

The user group for study A consists of two older adults that do not own a VR headset. The first group will be included to involve users of the target group and evaluate their experiences.

7.2.4 Materials

7.2.4.1 Prototypes

Beach2D and Forest2D will be used. See Chapter 6 for more details on these prototypes.

7.2.4.2 Questions

A short questionnaire and a semi-structured interview will be conducted for this study. The questionnaire is attached in Appendix E. The interview questions are attached in Appendix F.

7.2.5 Procedure for study A

In this section, the protocol for study A will be described. The evaluation protocol can be divided into the following steps:

- Explanation
- Informed consent
- Instruction
- Test Beach2D
- Questionnaire and interview questions
- Test Forest2D
- Questionnaire and interview questions
- Interview questions on comparison Beach2D and Forest2D

Explanation and informed consent

Before conducting the interview, participants receive a short explanation

about the research. They receive an information brochure for further details about the research background, procedure, participation, data selection and storage and contact details for more information, independent advice or to file a complaint. They also sign a consent form and receive a copy of the consent form. The information brochure and consent form are attached in, respectively Appendix A and B. The tests will be done via a web conference application.

Instruction

The participant is instructed how to enable a video conference meeting via an instruction email and is guided how to view the different prototypes via AnyDesk[21] by the researcher. The participant is instructed how to interact with the different prototypes and the protocol will be explained.

Test

The participants interact with the Beach2D prototype, the participant fills in a short questionnaire and answer some interview questions. The participant interact with the Forest2D prototype, the participant fills in a short online questionnaire, attached in Appendix E, and answers the interview questions. The participant answers some interview questions on the comparison of Beach2D and Forest2D.

7.3 Study B

In this study, two older adults with a VR headset and three proxy users, persons with a VR headset but who do not belong to the target group because they are not older than 55 years, will evaluate the difference between the screen-based and VR experience.

7.3.1 Research question of Study B

In this study, the research question is: What is the difference in experience between Beach2D & BeachVR and Forest2D and ForestVR?

7.3.2 Method

[21] https://anydesk.com/nl [REF]

In this study the participants will interact with one of the screen-based prototypes (Beach2D or Forest2D) and the engagement is measured via a short questionnaire and a semi-structured interview. After that the participant interacts with protype in VR (Prototype BeachVR or ForestVR) and the engagement is measured via a questionnaire and semi-structured interview.

After both prototypes are shown, some questions will be asked to compare the different prototypes. The different variables are shown in table 3.

To counterbalance the tests, half of the users will start with the screen-based experience while the other half of the group starts with the VR experience. Half of the group will test the Beach prototypes and the other half the Forest prototypes.

Independent variables	Dependent variables
Screen based Prototype A	Level of engagement
VR Prototype A	User experience

Table 5: Study B variables

7.3.3 Participants

The user group for study B consists of two older adults with a VR headset and three proxy users, persons with a VR headset but who do not belong to the target group because they are not older than 55 years, will evaluate the difference between the screen-based and VR experience.

The target user group is older adults. Due to the COVID regulations, proxy users are also involved. Therefore persons who do own a VR headset but do not belong to the target group are involved to evaluate the aspects in VR and complement and broaden the analysis from the second user group. The proxy users will be asked to interact with the prototypes as if they have low experience with VR as found for older adults in chapter 2.2.1.

7.3.4 Materials

7.3.4.1 Prototypes

Beach2D, BeachVR, Forest2D and ForestVR will be used. See Chapter 6 for more details on these prototypes.

7.3.4.2 Questions

A short questionnaire and semi-structured interviews will be conducted for this study. The questionnaire is attached in Appendix E. The interview questions are attached in Appendix F.

7.3.5 Procedure

In this section, the protocol for study B will be described. The evaluation protocol can be divided into the following steps:

- Explanation
- Informed consent
- Instruction
- Test Beach2D
- Questionnaire and interview questions
- Test BeachVR
- Questionnaire and interview questions
- Interview questions on difference screen-based and VR experience (Beach 2D vs. BeachVR or Forest2D vs. ForestVR)

Explanation and informed consent

Before conducting the interview, participants receive a short explanation about the research. They receive an information brochure for further details about the research background, procedure, participation, data selection and storage and contact details for more information, independent advice or to file a complaint. They also sign a consent form and receive a copy of the consent form. The information brochure and consent form are attached in, respectively Appendix A and B. The tests will be done via a web conference application.

Instruction

The participant is instructed how to interact with the different prototypes and the protocol will be explained.

Test

The participant will interact with Beach2D prototype, the participant fills in a short questionnaire and answer some interview questions. The participant will interact with the prototype BeachVR, the participant fills in a short questionnaire and answer some interview questions. The participant answers some interview questions on the difference between the screen-based and VR experience (Beach 2D vs. BeachVR or Forest2D vs. ForestVR).

7.4 Study C

In Study C, older adults with a VR headset and proxy users, persons with a VR headset but who do not belong to the target group, will evaluate the difference between the BeachVR and ForestVR.

7.4.1 Research question of Study C

In this study, the research question is: What is the effect of the different components on the experience between BeachVR and ForestVR?

7.4.2 Method

In this test the participant will interact with the BeachVR prototype and the engagement is measured via a short questionnaire and a semi-structured interview. After that the users will interact with the ForestVR prototype and the engagement is measured via a short questionnaire and a semi-structured interview. To counterbalance the tests, half of the users will start with the BeachVR prototype while the other half of the group starts with the ForestVR prototype. After both prototypes are shown, some questions will be asked to compare the different prototypes. The different variables are shown in table 3.

Independent variables	Dependent variables
BeachVR	Level of engagement
ForestVR	User experience

Table 6: Study C variables

7.4.3 Participants

The user group for study B consists of two older adults with a VR headset and three proxy users, persons with a VR headset but who do not belong to

the target group because they are not older than 55 years, will evaluate the difference between the screen-based and VR experience.

The target user group is older adults. Due to the COVID regulations, proxy users are also involved. Therefore persons who do own a VR headset but do not belong to the target group are involved to evaluate the aspects in VR and complement and broaden the analysis from the second user group. The proxy users will be asked to interact with the prototypes as if they have low experience with VR as found for older adults in chapter 2.2.1.

7.4.4 Materials

7.4.4.1 Prototypes

BeachVR and ForestVR will be used. See Chapter 6 for more details on these prototypes.

7.4.4.2 Questions

A short questionnaire and semi-structured interviews will be conducted for this study. The questionnaire is attached in Appendix E. The interview questions are attached in Appendix F.

7.4.4.3 Procedure

In this section, the protocol for study C will be described. The evaluation protocol can be divided into the following steps:

- Explanation
- Informed consent
- Instruction
- Test BeachVR
- Questionnaire and interview questions
- Test ForestVR
- Questionnaire and interview questions
- Interview questions on comparison BeachVR and ForestVR

Explanation and informed consent

Before conducting the interview, participants receive a short explanation about the research. They receive an information brochure for further details

about the research background, procedure, participation, data selection and storage and contact details for more information, independent advice or to file a complaint. They also sign a consent form and receive a copy of the consent form. The information brochure and consent form are attached in, respectively Appendix A and B. The tests will be done via a web conference application.

Instruction

The participant is instructed how to interact with the different prototypes and the protocol will be explained.

Test

The participant will interact with the BeachVR prototype, the participant fills in a short questionnaire and answer some interview questions. The participant will interact with the ForestVR prototype, the participant fills in a short questionnaire and answer some interview questions. The participant answers some interview questions on the difference between the prototypes BeachVR and ForestVR.

7.5.1 Method for analysis

The results of the questionnaire will be analysed according to the researchers of the questionnaire.

7.5.1.1 Scoring the UES-SF

All items of the questionnaire will be randomized and the dimension identifiers (FA, PU, AE or RW, see appendix E) will not be visible to the user. A five-point rating will be used to allow for comparisons across studies and populations.

For the scoring the following steps will be done:

- Reverse code PU-S1, PU-S2, PU-S3
- If participants have completed the UES more than once as part of the same experiment, calculate separate scores for each iteration. This will enable the researcher to compare engagement within participants and between tasks/iterations.

- Scores for each of the four subscales will be calculated by adding the values of responses for the three items contained in each subscale and dividing by three.
- An overall engagement score can be calculated by adding all of the items together and dividing by twelve.

7.5.1.2 Analysing the interview

The qualitative data of the semi-structured interviews will be analysed according to the following method.

- Prepare and organize the data. The transcripts of the interview will be collected.
- Review and explore the data. Read through the answers and note the questions, ideas or thoughts.
- Create initial codes. Use sticky pads or highlighters to note key words, phrases and categories.
- Review those codes and revise or combine into themes. Identify recurring themes, language, opinions, and beliefs.
- Present themes in a cohesive manner.
- Consider your audience, the purpose of the study, and what content should be included to best tell the story of your data.

7.5 Execution

7.5.1 Pilot test

For each study a pilot test was conducted. The pilot tests were conducted to test the protocol and prototype. The pilot test for Study A learned that the participant should take control of the screen/interaction after the researcher disabled the moves for the agents . The pilot tests for Study B and C learned that the research had to control the canvas, camera and EventSystem in Unity before starting the prototype.

7.5.2 Study A

In this test the dialogues were repeated multiple times, in most of the cases two times, to make sure the participant had enough time to inspect the prototype and interact with the prototype. The participants also needed some

guidance in answering the questionnaires. They needed help with translating or understanding the statement.

7.5.3 Study B

In this test the dialogues were repeated multiple times, in most of the cases two times, to make sure the participant had enough time to inspect the prototype and interact with the prototype. Next to that some problems occurred with the tracking of the participants location to control the GazePointer to select the desired moves. This was fixed by setting up the Quest from the beginning again so the right position for the participant was used.

7.6.4 Study C

In this test the prototypes were repeated multiple times to make sure the participant had enough time to inspect the prototype and interact with the prototype. Next to that some problems occurred with the tracking of the participants location to control the GazePointer to select the desired moves. This was fixed by setting up the Quest from the beginning again so the right position for the participant was used.

7.6 Results

The results of the different studies and an overall discussion of the evaluation results will be described in this section.

7.6.1 Study A

The goal of this study was to find an answer on the research question for study A: What is the effect of the different components in Beach2D and Forest2D on older adults? This was evaluated with the prototypes, questionnaires and the semi-structured interview as described in chapter 7.2.

Questionnaire

Although the sample size for this study was only two and the questionnaire results are not statistically valid, it could give an indication of the differences in engagement and compare these results with the qualitative data from the semi-structured interview. The results of the questionnaires are attached in Appendix G and the overall engagement scores for each participant are shown in Table 7.

These scores are calculated following the description in 7.5.1.1. The first participant was a 82 year old female and the second participant was a 81 year old male. The questionnaire results for study A showed a preference for the Forest2D prototype for both participants. The engagement scores went from 3.83 to 4.08 and from 3.33 to 3.83.This result shows us the overall preferred screen-based prototype of the participants but does not say anything about the different components in these prototypes since the questionnaire is not focused on the different components.

Participant	#1	#2
Beach2D	3.83	3.33
Forest2D	4.083	3.83

Table 7: Engagement scores study A

Interview

For the effect of the different components, a look at the results of the semi-structured interview could help. The interviews were analysed according to section 7.5.1.2. The reoccurring themes with respect to the different components were that the forest was preferred by both participants of this study because of the view perspective, calming effect and the natural environment. The participants preferred an environment that would not have the couch, table and house component. Both participants did not see the point for the couch only than the location to sit, table was too dominant and the house limited the view. One of the participants preferred the chairs from the Beach2D prototype while the other one preferred the chairs from the Forest2D prototype.

7.6.2 Study B

The goal of this study was to find an answer on the research question for study B: What is the difference in experience between Beach2D & BeachVR and Forest2D and ForestVR?

This was evaluated with the prototypes, questionnaires and the semi-structured interview as described in chapter 7.3.

Questionnaire

Although the sample size for this study was only five and the questionnaire

results are not statistically valid, it could give an indication of the differences in engagement and compare these results with the qualitative data from the semi-structured interview. The results of the questionnaires are attached in Appendix G and the overall engagement scores for each participant are shown in Table 8. These scores are calculated following the description in 7.5.1.1. The questionnaire results for study B showed that for four out of five participants the overall engagement increased for the VR prototypes (Beach2D vs. BeachVR as well as Forest2D and ForestVR), for participant #4 the engagement score was the same.

Participant	#3	#4	#5	Participant	#6	#7
Forest2D	3.33	4.083	3.33	Beach2D	2.66	3.83
ForestVR	3.92	4.083	3.83	BeachVR	3.66	4.5

Table 8: Engagement scores study B

Interview

The interviews were analysed according to section 7.5.1.2. The reoccurring themes with respect to the screen-based and the VR prototypes were that the VR prototypes were seen as more realistic, giving a better experience and more immersion. This was because the VR allowed the participants to get surrounded by the environments and see more details.

7.6.3 Study C

The goal of this study was to find an answer on the research question for study B: What is the effect of the different components on the experience between BeachVR and ForestVR?

This was evaluated with the prototypes, questionnaires and the semi-structured interview as described in chapter 7.4.

Questionnaire

Although the sample size for this study was only five and the questionnaire results are not statistically valid, it could give an indication of the differences in engagement and compare these results with the qualitative data from the semi-structured interview. The results of the questionnaires are attached in Appendix G and the overall engagement scores are shown in Table. The questionnaire results for study C showed a preference for the

ForestVR prototype for participants #5, #6 and #7, while the questionnaire results for participants #3 and #4 indicate a preference for BeachVR. This result does not clearly show us the overall preferred prototype of the participants and does not say anything about the different components in these prototypes since the questionnaire is not focused on the different components. The qualitative data from the semi-structured interview might help clarify richer results.

Participant	#3	#4	#5	#6	#7
BeachVR	4.00	4.33	3.00	3.66	4.50
ForestVR	3.92	4.083	3.83	3.75	4.75

Table 9: Engagement scores study C

Interview

The interviews were analysed according to section 7.5.1.2. The reoccurring themes with respect to the different VR prototypes were that the forest environment was preferred because of the looks, feeling and view. Only one out of five participants preferred the beach because of the sound and the ability to look further on the sea than in the forest. Four out of the five participants from this study preferred the outdoor experience as in the forest because the house limits the view. Two participants mentioned that the indoor experience gave them a better feeling of privacy but only one preferred that over the unlimited view of the environment. Some participants liked the table component because it created a situation more like a regular conversation while others saw the table as a component that created distanced between the agents and the users. Some participants liked the chairs from the beach because of the nicer component while others thought that the chairs from the forest were less distracting and outstanding.

7.6.4 Overall discussion of results

The three studies gave some good insight into the different components of the prototypes and how they affect the users engagement and experience.

Study A showed that the Forest2D protypes was preferred for both participants because of the view perspective, calming effect and the natural environment. The participants preferred an environment that would not have

the couch, table and house component. Both participants did not see the point for the couch only than the location to sit, table was too dominant and the house limited the view. One of the participants preferred the chairs from the Beach2D prototype while the other one preferred the chairs from the Forest2D prototype.

Study B showed that the participants preferred the VR prototypes over the screen-based prototypes because the VR prototypes were seen as more realistic, giving a better experience and more immersion. The questionnaire results for study B showed that for four out of five participants the overall engagement increased for the VR prototypes.

Study C showed that the ForestVR prototype was preferred over the BeachVR because of the looks, feeling and view. The questionnaire results for study C showed a preference for the ForestVR prototype for participants #5, #6 and #7, while the questionnaire results for participants #3 and #4 indicate a preference for BeachVR. Four out of the five participants from this study preferred the outdoor experience as in the forest because the house limits the view. There were some mixed opinions about the couch, table and chairs components. The couch helped to create a cosy place in the BeachVR prototype but would not fit in the ForestVR prototype. Some participants liked the table because it created a more serious and regular conversation feeling, while on the other hand participants disliked it because it created a distanced between the agents and the user. Some participants liked the chairs from the beach because of the nicer component while others thought that the chairs from the forest were less distracting and outstanding.

Overall the three studies showed a recommendation for the forest environment in Virtual Reality. The forest environment because of the looks, feeling and view and the Virtual Reality because it was seen as more realistic, giving a better experience and more immersion. The participants preferred the outdoor experience because of the unlimited view. The participants preferred the chairs from the beach prototypes but preferred a less distracting and outstanding colour for the forest environment. The opinions about the couch and table were mixed.

8 Conclusion

The conclusion of this report will start by summarising the findings from the evaluation, where conclusions can be drawn about the design recommendation for the Council of Coaches system in Virtual Reality. The section will end with answering the research questions posed at the start of this report.

Overall the three studies showed a recommendation for the forest environment in Virtual Reality. The forest environment because of the looks, feeling and view and the Virtual Reality because it was seen as more realistic, giving a better experience and more immersion. The participants preferred the outdoor experience because of the unlimited view. The participants preferred the chairs from the beach prototypes but preferred a less distracting and outstanding colour for the forest environment. The opinions about the couch and table were mixed.

For this report the main research questions was:

- How can a new 3D modelled environment influence the engagement of older adults with the Council of Coaches system in Virtual Reality?

To answer the main research question the following sub questions were posed:

- What are the factors influencing the engagement of older adults with Virtual Reality?
- What are the factors influencing the engagement of older adults with the Council of Coaches system?
- What factors of the 3D environment are influencing the engagement of older adults with the Council of Coaches system in Virtual Reality?

What are the factors influencing the engagement of older adults with Virtual Reality?

The literature showed the benefits of VR: improving the quality of life of older adults, allows needs and circumstances to be tailored to older adults, positive results on medical health, assistance in recovery of cognitive disorders, balancing recovery, enhance health despite physical and mental disabilities, improve social relationships, no external constraints like weather, allow older adults to travel in VR, teach and offer practical knowledge, personal regulating of training intensity, unconscious learning mechanisms, train lower limbs, coordination, agility training, cognition and balance and help reach the daily recommended activities for the older population. Most of these benefits cannot be seen as factors that directly influence the engagement but this benefits can contribute to a more engaged use of Virtual Reality once the user understands and discovers these benefits it can improve their engagement.

Next to the benefits, barriers towards VR were found. These barriers are being costly, not widely and easily available, low experience in use of VR, need for preparation, resistance and rejection by the elderly, as well as fear and negative attitude of the elderly in the virtual world, technology that should be researched and carefully considered in the first place to achieve the best results, problems that elderly people have with using the mouse and likely eye problems from wearing the 3D glasses and the fact the senior population, in general, suffers from technical illiteracy.

VR designers should keep in mind to use these benefits while designing a new VR experience while also prevent barriers from damaging the experience. VR designers should design with the focus to create for users that are low experienced in VR, might resist, reject, fear or have a negative attitude towards VR, have interaction problems or technical illiteracy.

What are the factors influencing the engagement of older adults with the Council of Coaches system?

The relation between COUCH and older adults was researched. It showed that the Council of Coaches technology can and should fulfil the following tasks: Health education, providing reminders, motivating clients to adhere to medication or training regimes, social support, and health monitoring. The stakeholders argued the importance of independence, supporting, transparency, positivity in the features in COUCH.

What factors of the 3D environment are influencing the engagement of older adults with the Council of Coaches system in Virtual Reality?

The success with which an immersive digital environment can actually immerse the user is dependent on many factors such as believable 3D computer graphics, surround sound, interactive user-input and other factors such as simplicity, functionality and potential for enjoyment.

This research found that the engagement of older adults with the COUCH system in VR can be influenced by the use of different environments, sounds, interaction mechanisms, screen-based or VR experience, indoor or outdoor experience, the use of a couch, table and different chairs.

Granting older adults access to technology, which may otherwise be out of their reach is a very good way to guarantee engagement, and usually it is enough to convince them to participate in the development process. Additionally, the whole team and the users alike need to feel that their insights are appreciated and valued, so it is key to schedule the meetings with enough time for digression and extensive questions about the technology or the project itself.

How can a new 3D modelled environment influence the engagement of older adults with the Council of Coaches system in Virtual Reality?

The engagement of older adults with the Council of Coaches system in Virtual Reality can be influenced by different components. In this project the effects of different environments, sounds, interaction mechanisms, screen-based or VR, indoor or outdoor experience, the use of a couch, table and different chairs were researched. The evaluation found that the forest environment was preferred because of the looks, feeling and view and the Virtual Reality because it was seen as more realistic, giving a better experience and more immersion. The participants preferred the outdoor experience because of the unlimited view. The participants preferred the chairs from the beach prototypes but preferred a less distracting and outstanding colour for the forest environment. The opinions about the couch and table were mixed. This research found that the engagement of older adults with the COUCH system in VR can be influenced by the use of different environments, sounds, interaction mechanisms, screen-based or VR experience, indoor or outdoor experience, the use of a couch, table and different chairs.

Considering the screen-based interaction version of COUCH and the potential benefits of VR on the human-computer interaction of COUCH, it was interesting to integrate and improve the Council of Coaches system in VR with the target group of older adults in mind and to see that the levels of engagement increased and the user experience was improved.

9 Discussion

This chapter will discuss the execution of the conducted research, the prototypes and evaluation. Next to that recommendations for future work will be done.

The built prototypes have some issues that either fell out of scope of this research to fix, or came to light during the evaluation phase. The researcher had to manually disable the components of the dialogue to only show the users' move options. This could have been arranged automatically by make some adjustments to the scripts that control the moves. Next to that, the Quest was used as an Oculus Rift. This is not optimal because it has lower image quality and the headset should be connected to the PC through a USB cable. For future research more time to manage technical issues should be fit into the planning.

This research has been conducted with the use of four older adults and three proxy users. Two of these older adults had access to a VR headset and could test the full experience in VR. To include the non VR headset owners a different study was designed. For future research, more users of the target group could be used. Not only could this be for more users but also to make sure the evaluation is more statistically valid. The current questionnaires could only be used for indications while with more users it could be used to draw direct conclusions without having to confirm or deny the findings via the interview results.

Overall the three studies showed a recommendation for the forest environment in Virtual Reality. The forest environment because of the looks, feeling and view and the Virtual Reality because it was seen as more realistic, giving a better experience and more immersion. The participants preferred the outdoor experience because of the unlimited view. The participants preferred the chairs from the beach prototypes but preferred a less distracting and outstanding colour for the forest environment. The opinions about the couch and table were mixed.

Looking at these results, it can be learned that VR is preferred over screen-based and it could increase the engagement. Thus, for the COUCH concept, it is interesting to consider moving the system to a VR experience. In future research the feasibility to use VR as the standard experience could be researched. Questions about the compatibility, accessibility, costs, interaction and long term effect on engagement for the complete system have to be researched.

For future designs for the environment, it can be learned from this research that users prefer an outdoor experience, where there is a view on a natural and inspiring environment like the forest environment with the council meeting happening in a Virtual Reality environment.

Future research could also look at the option to allow user to give their own personalization to the environment and the components and the effect on the engagement.

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Appendix A: Information Brochure Interview on Council of Coaches in Virtual Reality

Information brochure Interview on Council of Coaches in Virtual Reality

In this brochure, we would like to inform you about the research you have applied to participate in.

Research assistant: Timo Petersen

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Tel.: +31651052430

E-mail: t.g.petersen@student.utwente.nl

UNIVERSITY OF TWENTE.

Background

Council of Coaches (COUCH) is an autonomous, multiagent and interactive demonstrator that allows the user to participate in a virtual council meeting to motivate and inform about health and wellbeing related issues, including physical, social, cognitive and mental support. These coaches interact with the user and each other to inform, motivate and discuss issues to the user's health and well-being to set and pursue goals to improve their health.

COUCH takes the next step to integrate different health services to provide older adults with a personal integrated coaching experience and improve the affordability of health care, increase the quality level of health care and increase the efficiency of the deployment of health care workers.

The aim of this research project is to research how a new 3D modelled environment can influence the engagement of older adults with the Council of Coaches system in Virtual Reality. In this project, the goal is to design a

3D environment for COUCH in VR that fits the target group of older adults and to test the development on older adults.

Research procedure

The experiment will take place in the period of May and June 2020 via an online video meeting. The experiment will take 20 minutes for the user confrontation. The experiment in the evaluation phase will take 60 minutes.

In the proposed research, entitled “Council of Coaches in Virtual Reality”, pictures, videos or VR environments are presented and observations and answers on interview questions and questionnaires will be registered.

The research project has been reviewed and approved by the EEMCS Ethics Committee.

Participation

The participant can decide to stop at any point in the course of the experiment without this having any consequences for yourself and without giving any reasons. The participants will not be paid. At the end of the entire research, the participant may, if the participant wishes, be informed about the results obtained by means of a debriefing.

The participants that do not interact with a VR headset will not be screened.

Participants that will interact with a VR headset are screened on the following things:

- The participants who had a seizure, loss of awareness, or other symptom linked to an epileptic condition.
- Participants who are pregnant, elderly, have pre-existing binocular vision abnormalities or psychiatric disorders, or suffer from a heart condition or other serious medical condition.
- The participants who have a pacemaker or other implanted medical device.

If one of these is the case, the participant will be excluded from this experiment to reduce risks of adverse effects.

Data selection and storage

Observations and answers on interview questions and questionnaires will be

registered. The VR scenes that are shown display an environment (e.g. office, beach, forest.) where a meeting takes place between the user and virtual agents. Questions will be asked about their opinion on the environment, their interaction and immersion with the VR scene.

The video recording of these VR scenes will be shown to some participants (older adults that do not own a VR headset) and they will be asked about their opinion on the environment of the VR scene.

The registered data of the patient will be handled in a confidential manner, the anonymity of your data is guaranteed and will never be disclosed to third parties without your permission. The participant can still decide at the end of the research and up to 24 hours thereafter, that their data may not be included in the research after all.

More information and independent advice

If the participant wants independent advice about participating in this research, or file a complaint the participant can contact the ethics committee. This is a committee of independent experts and is available for questions and complaints about this research.

For other questions the participant can contact the research assistant.

Contact details ethics committee

Faculty of EEMCS

University of Twente

P.O. Box 217, 7500 AE Enschede (NL)

E-mail: ethics-comm-ewi@utwente.nl

DRS. P. De Willigen

Tel.: +31534892085

Appendix B: Informed Consent for Interview on Council of Coaches in Virtual Reality.

'I, the participant of the experiment, hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned information brochure 'Interview on Council of Coaches in Virtual Reality'. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. I have been sent a copy of this consent form. I declare that I do not belong to one of the following excluded participant groups.'

- The participants who had a seizure, loss of awareness, or other symptom linked to an epileptic condition.
- The participants who are pregnant, elderly, have pre-existing binocular vision abnormalities or psychiatric disorders, or suffer from a heart condition or other serious medical condition.
- The participants who have a pacemaker or other implanted medical device.

If you request further information about the research, now or in the future, you may contact Timo Petersen, email: t.g.petersen@student.utwente.nl. If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, P.O. Box 217, 7500 AE Enschede (NL), email: ethics-comm-ewi@utwente.nl).

_____ Date

_____ Signature

_____ Name

I, the investigator, have provided explanatory notes about the research. ‘I declare myself willing to answer to the best of my ability any questions which may still arise about the research.’

_____ Date

_____ Name of the Investigator

_____ Signature of the Investigator

Appendix C: Interview procedure and question list

Inform participants

Introduce the potential participant to the research, share the information brochure and consent form.

Introduction COUCH

Council of Coaches (COUCH) is an autonomous, multiagent and interactive demonstrator that allows the user to participate in a virtual council meeting to motivate and inform about health and wellbeing related issues, including physical, social, cognitive and mental support. The council consist of several Embodied Conversational Agents (ECAs) and each virtual character has its expertise, personality and style of coaching. The expertise is on various domains including physical activity, cognitive and mental health, social skills and participation, as well as condition-specific expertise for diabetes and chronic pain [6]. The council meeting will take place between the ECAs and the user. The coaches consist of a diet, physical activity, mental, social coach or a peer. These coaches interact with the user and each other to inform, motivate and discuss issues to the user's health and well-being. The coaches will listen to, inform, help and motivate the user to set and pursue goals to improve their health. The user than share its developments and questions with the council or listen and observe how the different virtual characters discuss their opinions. The user can use the suggestions and lessons in its daily life and contact the virtual characters anytime, anywhere. COUCH takes the next step to integrate different health services to provide older adults with a personal integrated coaching experience and improve the affordability of health care, increase the quality level of health care and increase the efficiency of the deployment of health care workers.

Video of the prototype with the agents

The following video is shown to give the participants an idea about the ECAs, environments and the conversation dialogue :

Final Prototype - GRETA and ASAP Agents in one scene (2 vs 2). 2020. Accessed at 7 June 2020 at https://www.youtube.com/watch?v=ZYCUnEsVPjo

Concepts

The concepts of section 4.2 will be shown.

Interview

The following questions are asked:

- What is your age?
- Are you familiar with Virtual Reality?
- Do you know possibilities in Virtual Reality or applications of the technology?
- What components of the environment do you think that are important during the conversation?
- In what kind of environment do you prefer to receive personal advice?
- What do you think of the environment? * For each concept
- Which one feels most realistic?
- Which one feels most personal?
- Which one motivates the most to keep listening?
- Does it feel realistic?
- Would you prefer sitting down, standing or walking around during the conversation?
- Would you prefer the conversation takes place indoor or outdoor in the VR environment?
- What kind of environment do you prefer?
- Which concept do you prefer?

Appendix D: Minutes of the interviews in the Ideation phase

Participant #1

- **What is your age?**
  52
- **Are you familiar with Virtual Reality?**
  Yes, I have seen some travel videos in VR.
- **Do you know possibilities in Virtual Reality or applications of the technology?**
  No not that much, I do know that you can watch around in 360.
- **What components of the environment do you think that are important during the conversation?**
  No distraction from the background, natural conversations, friendly face expressions of the agents and soothing environment.
- **In what kind of environment do you prefer to receive personal advice?**
  Daylight, nature, landscape.
- **What do you think of the environment? * For each concept**
  Likes the cabin of the environment of the forest concept and nature. Likes the beach and view. Likes feeling of being outside but questions feeling of privacy and confidence in VR. The general practitioner office feels to business like and unpersonal. The general practitioner office is often not a place that feels comfortable. Living room is okay but paintings or other things can distract you. Prefers a view outside. Space concept feels unnatural, VR already is an uncommon technology so does not feel very personal. Prefers a wide an broad view instead of nature in the garden.
- **Which one feels most realistic?**
  The forest
- **Which one feels most personal?**
  The beach
- **Which one motivates the most to keep listening?**
  The forest or the beach.
- **Would you prefer sitting down, standing or walking around during the conversation?**
  Sitting down
- **Would you prefer the conversation takes place indoor or outdoor in the VR environment?**
  Indoor, thinks that feeling of indoors can provide feeling of privacy, even if it is in VR.
- **What kind of environment do you prefer?**
  The forest or the beach, wide view.
- **Which concept do you prefer?**
  The beach, but it would be better if it was indoor.

Participant #2

- **What is your age?**
  50
- **Are you familiar with Virtual Reality?**
- Yes, I have seen a travel video in VR and played a game in VR.
- **Do you know possibilities in Virtual Reality or applications of the technology?**
  Yes, I know that you can play realistic games and user your hands to control things. You can place yourself in a different environment,
- **What components of the environment do you think that are important during the conversation?**
  A realistic environment, more humanlike agents than the current ones, personal interaction, feeling of human experience.
- **In what kind of environment do you prefer to receive personal advice?**
  A spacious place that feels comfortable and provides some place for privacy. The ambiance of the room is important.
- **What do you think of the environment? * For each concept**
- I like the trees and the feeling of being in a forest. I like the beach but would prefer inside conversation. The general practitioner offices could be used but depends on what type of conversation. Would prefer a place with better ambience. The living room is a place that feels safe but if it is not your own it might feel distracting. The space concept makes me feel awkward and not realistic, makes the conversation feel to computer controlled. Prefers nature, peaceful environment with sky or clouds. The garden concept is liked because of the green but mentions sheltered could be an option. A wooden cabin or small house in the garden would be a nice place.
- **Which one feels most realistic?**
  The garden or living room
- **Which one feels most personal?**
  The forest or the beach. Away from daily environment.
- **Which one motivates the most to keep listening?**
  The forest.
- **Would you prefer sitting down, standing or walking around during the conversation?**
  I would prefer walking around during the conversation but since walking around is not very possible I would like to sit in front of the agents.
- **Would you prefer the conversation takes place indoor or outdoor in the VR environment?**
  Indoor with a view outside
- **What kind of environment do you prefer?**
  The forest or the beach. Places with nature, a view, peaceful surroundings.

- **Which concept do you prefer?**
  The forest or beach. As long as there is a sheltered place with a view, water, sea or trees or high in the sky.

Appendix E: Questionnaire User engagement

User Engagement Scale Long Form (UES-SF).

https://www.sciencedirect.com/science/article/pii/S1071581918300041

The following statements ask you to reflect on your experience of engaging with Application X or "this study". For each statement, please use the following scale to indicate what is most true for you.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

FA-S.1	I lost myself in this experience.
FA-S.2	The time I spent using Application X just slipped away.
FA-S.3	I was absorbed in this experience.
PU-S.1	I felt frustrated while using this Application X.
PU-S.2	I found this Application X confusing to use.
PU-S.3	Using this Application X was taxing.
AE-S.1	This Application X was attractive.
AE-S.2	This Application X was aesthetically appealing.
AE-S.3	This Application X appealed to my senses.
RW-S.1	Using Application X was worthwhile.
RW-S.2	My experience was rewarding.
RW-S.3	I felt interested in this experience.

The questionnaire will be asked via a Google Form that is shown in the figures below.

User Enagement Questionnaire (UES-SF)

The following statements ask you to reflect on your experience of engaging with the prototype. For each statement, please use the following scale to indicate what is most true for you.

* Required

1. I lost myself in this experience. *

   Mark only one oval.

   - ◯ Strongly disagree
   - ◯ Disagree
   - ◯ Neither agree nor disagree
   - ◯ Agree
   - ◯ Strongly agree

2. The time I spent using this prototype just slipped away. *

   Mark only one oval.

   - ◯ Strongly disagree
   - ◯ Disagree
   - ◯ Neither agree nor disagree
   - ◯ Agree
   - ◯ Strongly agree

3. I was absorbed in this experience *

   Mark only one oval.

   - ◯ Strongly disagree
   - ◯ Disagree
   - ◯ Neither agree nor disagree
   - ◯ Agree
   - ◯ Strongly agree

4. I felt frustrating while using this prototype *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

5. I found this prototype confusing to use *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

6. Using this prototype was taxing *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

7. This prototype was attractive *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

8. This prototype was aesthetically appealing *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

9. This prototype appealed to my senses *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

10. Using this prototype was worthwile *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

11. My experience was rewarding *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

12. I felt interested in this experience *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

Appendix E: Interview questions evaluation

The following questions will be asked for study A:

- How did you experience the environment?
- What do you like about the environment?
- What do you dislike about the environment?
- Would this environment be a place where you would discuss your health?
- Would you prefer sitting down, standing or walking around during the conversation?
- Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Beach prototypes questions:

- What is your opinion about the beach component in this environment?
- What is your opinion about the couch in this environment?
- What is your opinion about the table in this environment?
- What is your opinion about the chairs in this environment?
- What is your opinion about the beach house in this environment?

Forest prototypes questions:

What is your opinion about the forest environment?

Questions for comparison of prototypes

- Which prototype do you prefer? Why?
- Which environment do you prefer? Why?
- Do you prefer the inside or outside conversation? Why?
- Do you prefer the stationary or room-scale experience? Why?
- What is your opinion about the couch, table and chairs?
- What is your opinion about the beach house?
- Should the forest include this as well or leave it out?

UI, agents, conversation, control, audio, etc?

And the why's?

The following questions will be asked for study B:

- How did you experience the environment?
- What do you like about the environment?
- What do you dislike about the environment?
- Would this environment be a place where you would discuss your health?
- Would you prefer sitting down, standing or walking around during the conversation?
- Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Beach prototypes questions:

- What is your opinion about the beach component in this environment?
- What is your opinion about the couch in this environment?
- What is your opinion about the table in this environment?
- What is your opinion about the chairs in this environment?
- What is your opinion about the beach house in this environment?

Forest prototypes questions:

What is your opinion about the forest environment?

Questions for comparison of prototypes

- Which prototype do you prefer? Why?
- What is your opinion on the difference between the 2D and VR protoypes?
- Is the environment in VR more immersive or is it unnecessary?

The following questions will be asked for study C:

- How did you experience the environment?
- What do you like about the environment?
- What do you dislike about the environment?
- Would this environment be a place where you would discuss your health?
- Would you prefer sitting down, standing or walking around during the conversation?
- Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Beach prototypes questions:

- What is your opinion about the beach component in this environment?
- What is your opinion about the couch in this environment?
- What is your opinion about the table in this environment?
- What is your opinion about the chairs in this environment?
- What is your opinion about the beach house in this environment?

Forest prototypes questions:

What is your opinion about the forest environment?

Questions for comparison of prototypes

- Which prototype do you prefer? Why?
- Which environment do you prefer? Why?
- Do you prefer the inside or outside conversation? Why?
- Do you prefer the stationary or room-scale experience? Why?
- What is your opinion about the couch, table and chairs?
- What is your opinion about the beach house?
- Should the forest include this as well or leave it out?

Appendix F: Dialogue protocol

```
System{GoalSetting{
        /* Description: A game to discuss a physical activity goal */
        turns{magnitude:multiple, ordering:liberal}
        roles{Person}
        players{min:2, max:3}
        player{id:Agent, roles{Person}, max:2, min:1}
        player{id:User, roles{Person}, max:1, min:1}
        backtrack{on}
 rule{id:StartingRule, scope:initial,
  {
     assign(Agent, speaker)
     & move(add, next, Intro, $User, {p}, Agent)
  }}
 /* Start with an introduction */
 interaction{Intro, $User, {p}, "$p",
  {
    assign(User, speaker)
    & move(add, next, Agreed, $Agent, {p}, User)
    & move(add, next, Disagreed, $Agent, {p}, User)
                        & save({p}, $AgreedGoal$)
  }}
 interaction{Agreed, $Agent, {p}, "$p",
  {
    assign(User, speaker)
```

```
& move(add, next, Goodjob, $User, {p}, Agent)
   }}
  interaction{Goodjob, $Agent, {p}, "$p",
   {
     assign(User, speaker)
& move(add, next, Goalagreed, $Agent, {p}, User)
& move(add, next, Goalquestioned, $Agent, {p}, User)
   }}
   interaction{Disagreed, $Agent, {p}, "$p",
   {
     assign(User, speaker)
& move(add, next, Betterjob, $User, {p}, Agent)
   }}
  interaction{Betterjob, $Agent, {p}, "$p",
   {
     assign(User, speaker)
& move(add, next, Goalagreed, $Agent, {p}, User)
& move(add, next, Goalquestioned, $Agent, {p}, User)
   } }
  interaction{Goalagreed, $Agent, {p}, "$p",
   {
  assign(User, speaker)
& move(add, next, Coachend, $User, {p}, Agent)
  }}
```

```
interaction{Goalquestioned, $Agent, {p}, "$p",
   {
     assign(User, speaker)
& move(add, next, Motivation, $User, {p}, Agent)
   }}
   interaction{Coachend, $Agent, {p}, "$p",
   {
     assign(User, speaker)
& move(add, next, Intro, $User, {p}, Agent)
   } }
     interaction{Motivation, $Agent, {p}, "$p",
   {
     assign(User, speaker)
& move(add, next, Goalagreed, $Agent, {p}, User)
   }}
}}
```

Appendix G: Results Questionnaires

Study A

Participant and prototype	I lost myself in this experience.	The time I spent using this prototype just slipped away.	I was absorbed in this experience	I felt frustrating while using this prototype	I found this prototype confusing to use	Using this prototype was taxing	This prototype was attractive	This prototype was aesthetically appealing	This prototype appealed to my senses	Using this prototype was worthwile	My experience was rewarding	I felt interested in this experience	Overall Engagement Score
#1 Forest2D	Agree	Agree	Strongly agree	Disagree	Disagree	Strongly disagree	Agree	Strongly agree	Strongly agree	Agree	Agree	Strongly agree	4.083
#1 Beach2D	Disagree	Strongly agree	Neither agree nor disagree	Strongly disagree	Disagree	Strongly disagree	Agree	Neither agree nor disagree	Agree	Neither agree nor disagree	Agree	Agree	3.83
#2 Beach2D	Disagree	Agree	Agree	Strongly disagree	Disagree	Strongly disagree	Agree	Neither agree nor disagree	Neither agree nor disagree	Neither agree nor disagree	Agree	Agree	3.33
#2 Forest2D	Disagree	Strongly agree	Neither agree nor disagree	Strongly disagree	Disagree	Strongly disagree	Agree	Neither agree nor disagree	Agree	Neither agree nor disagree	Agree	Agree	3.83

Study B

Participant and prototype	I lost myself in this experience.	The time I spent using this prototype just slipped away.	I was absorbed in this experience	I felt frustrating while using this prototype	I found this prototype confusing to use	Using this prototype was taxing	This prototype was attractive	This prototype was aesthetically appealing	This prototype appealed to my senses	Using this prototype was worthwile	My experience was rewarding	I felt interested in this experience	Overall Engagement Score
#3 Forest2D	Disagree	Agree	Agree	Strongly disagree	Disagree	Strongly disagree	Agree	Neither agree nor disagree	Neither agree nor disagree	Neither agree nor disagree	Agree	Agree	3.33
#3 ForestVR	Neither agree nor disagree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Neither agree nor disagree	Agree	Agree	Strongly agree	3.92
#4 Forest2D	Agree	Agree	Agree	Strongly disagree	Disagree	Strongly disagree	Neither agree nor disagree	Neither agree nor disagree	Neither agree nor disagree	Agree	Agree	Strongly agree	4.08
#4 ForestVR	Agree	Agree	Strongly agree	Disagree	Disagree	Strongly disagree	Agree	Strongly agree	Strongly agree	Agree	Agree	Strongly agree	4.08
#5 Forest2D	Disagree	Agree	Agree	Strongly disagree	Disagree	Strongly disagree	Agree	Neither agree nor disagree	Neither agree nor disagree	Neither agree nor disagree	Agree	Agree	3.33
#5 ForestVR	Agree	Strongly agree	Strongly agree	Disagree	Neither agree nor disagree	Agree	Agree	Strongly agree	Neither agree nor disagree	Agree	Agree	Agree	3.83
#6 Beach2D	Disagree	Agree	Disagree	Disagree	Disagree	Disagree	Disagree	Disagree	Disagree	Disagree	Disagree	Disagree	2.66
#6 BeachVR	Disagree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Agree	Agree	Disagree	Agree	3.66
#7 Beach2D	Disagree	Strongly agree	Neither agree nor disagree	Strongly disagree	Disagree	Strongly disagree	Agree	Neither agree nor disagree	Agree	Neither agree nor disagree	Agree	Agree	3.83
#7 BeachVR	Agree	Strongly agree	Agree	Strongly disagree	Disagree	Strongly disagree	Strongly agree	Strongly agree	Strongly agree	Agree	Agree	Agree	4.50

Study C

Participant and prototype	I lost myself in this experience.	The time I spent using this prototype just slipped away.	I was absorbed in this experience	I felt frustrating while using this prototype	I found this prototype confusing to use	Using this prototype was taxing	This prototype was attractive	This prototype was aesthetically appealing	This prototype appealed to my senses	Using this prototype was worthwile	My experience was rewarding	I felt interested in this experience	Overall Engagement Score
#3 ForestVR*	Neither agree nor disagree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Neither agree nor disagree	Agree	Agree	Strongly agree	3.92
#3 BeachVR	Agree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	4.00
#4 ForestVR*	Agree	Agree	Strongly agree	Disagree	Disagree	Strongly disagree	Agree	Strongly agree	Strongly agree	Agree	Agree	Strongly agree	4.08
#4 BeachVR	Agree	Strongly agree	Strongly agree	Disagree	Disagree	Strongly disagree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Agree	4.33
#5 ForestVR*	Agree	Strongly agree	Strongly agree	Disagree	Neither agree nor disagree	Agree	Agree	Strongly agree	Neither agree nor disagree	Agree	Agree	Agree	3.83
#5 BeachVR	Neither agree nor disagree	Neither agree nor disagree	Disagree	Disagree	Agree	Agree	Neither agree nor disagree	Agree	Neither agree nor disagree	Neither agree nor disagree	Agree	Agree	3.00
#6 BeachVR*	Disagree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Agree	Agree	Disagree	Agree	3.66
#6 ForestVR	Disagree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Strongly agree	Agree	Agree	Disagree	Agree	3.75
#7 BeachVR*	Agree	Strongly agree	Agree	Strongly disagree	Disagree	Strongly disagree	Strongly agree	Strongly agree	Strongly agree	Agree	Agree	Agree	4.50
#7 ForestVR	Strongly agree	Strongly agree	Strongly agree	Disagree	Strongly disagree	Strongly disagree	Strongly agree	Strongly agree	Strongly agree	Agree	Agree	Strongly agree	4.75

* These results were taken from study B, so in study C only the different VR prototype had to be tested (BeachVR for partcicpant #3, #4, #5 and ForestVR for participant #6 and #7).

Appendix H: Minutes semi-structured interviews Evaluation phase

Study A

Participant #1

Forest2D

Forest prototypes questions:

What is your opinion about the forest environment?

I like the sun shining in the forest and the open spots in the environment.

What do you mean with open spots?

That you can look around through the trees.

Do you think that you can see enough?

I like that there is not that much going on besides the agents and the forest.

How did you experience the environment?

Pretty environment because of the sun and the trees.

What do you like about the environment?

The light from the sun shining through the threes.

What do you dislike about the environment?

The dry foreground/soil.

Would this environment be a place where you would discuss your health?

Yes, peaceful place where you can look around.

Would you prefer sitting down, standing or walking around during the conversation?

Sitting because that is more intimate.

Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Outside, I like the fact that you can look around in the forest.

Beach2D

Beach prototypes questions:

What is your opinion about the beach component in this environment?

It is boring, cannot see that much. I do like the view but there is not that much of the beach to see.

What is your opinion about the couch in this environment?

You do not really see it.

What is your opinion about the table in this environment?

The table is too dominant, it is too big and blocks the space.

What is your opinion about the chairs in this environment?

I like the chairs, they add color to the environment.

What is your opinion about the beach house in this environment?

I prefer to be in the open and look around like in the forest. The house limits what you can see.

Questions for comparison of prototypes

Which prototype do you prefer? Why?

I prefer the forest because you can look around and is a nicer environment than the beach.

Which environment do you prefer? Why?

The forest.

If there was no house component in the beach2D prototype, would you prefer the beach or the forest?

The forest because I like the trees and it is calming.

Do you prefer the inside or outside conversation? Why?

Outside, because of the view.

What is your opinion about the couch, table and chairs?

I like the chairs and they could fit into the forest prototype. Couch and table would not fit there.

What is your opinion about the beach house?

I do not like it because I prefer looking around.

Should the forest include this as well or leave it out?

Leave it out.

What is your opinion about the interaction?

It works fine with the selecting. In the beach prototype it was a little bit better because it was on the table.

What is your opinion about the audio?

I like the audio in both scenes. Add some more feeling and helps with relaxed feeling.

Participant #2

Beach2D

How did you experience the environment?

It looks like a room with a view on a sea or water. Gives me a nice, relaxing impression.

What do you like about the environment?

I like the perspective. The looking outside.

What do you dislike about the environment?

That it is not shiny weather. And the agents are sitting with their back to the view.

The user will sit on the couch and face the agents and can look outside.

Okay. Then the perspective is focused on the beach and the agents.

Would this environment be a place where you would discuss your health?

Yes,, calm environment.

Would you prefer sitting down, standing or walking around during the conversation?

Sitting down because in this setting that would work best.

What is your opinion about the beach component in this environment?

Beach is not very clean or it is because of the lightning. Maybe also the lighting from the floor is affecting the beach.

What is your opinion about the couch in this environment?

I do not really understand the couch component in this situation. In VR it might be a good thing.

What is your opinion about the table in this environment?

Helps to create a cosy place.

What is your opinion about the chairs in this environment?

Helps to create a cosy place.

What is your opinion about the beach house in this environment?

I like the floor because of the color.

Forest2D

What is your opinion about the forest environment?

It is a spectacular image. The background, beautiful old trees, nice see through view.

It is relaxing. The sun shines through the trees and creates a shadow. Gives a nice image.

Comparison

Which prototype do you prefer? Why?

Forest. More natural. More playful.

Do you prefer the inside or outside conversation? Why?

Outside. More playful, in the middle of the forest.

What is your opinion about the couch, table and chairs?

I thought the chairs were stones before but they do fit in the environment.. The blue chairs do not fit in this environment. Another colour might work. No table and couch gives more peace but is might be unclear for the user where to sit.

What is your opinion about the interaction?

The buttons could be a bit bigger..

What is your opinion about the audio?

Increases experience.

Study B

Participant #3
How did you experience the environment?

Clear questions. Next step could be explain how to reach those extra steps. Environment is relaxing.

What do you like about the environment?

The forest, the colours.

What do you dislike about the environment?

Nothing actually.

Would this environment be a place where you would discuss your health?

Yes, for sure.

Would you prefer sitting down, standing or walking around during the conversation?

Sitting. Maybe if the conversation is longer you could do a sort of walking experience.

Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Which prototype do you prefer? Why?

Virtual Reality. It gives you more the feeling that you are really in a conversation. You become part of the conversation.

What is your opinion on the difference between the 2D and VR protoypes?

The difference is that the VR gives more realism, the feeling that you are in a forest.

And how about the interaction? Do you prefer the mouse clicking or the GazePointer?

GazePointer if it is a little bit more finetuned.

Participant #4

How did you experience the environment?

Beautiful. Conversation is so short that I did not see very much the first time,

What do you like about the environment?

The view.

What do you dislike about the environment?

Nothing

Would this environment be a place where you would discuss your health?

Yes, looks nice.

Would you prefer sitting down, standing or walking around during the conversation?

Sitting down while listening and selecting answers is easier in my opinion.

What is your opinion about the forest environment?

Way more feeling in VR. More experience, realistic.

What is your opinion on the difference between the 2D and VR protoypes?

In VR is it way more realistic. You feel more present. You get immersed more. If I could choose to do it in VR or screenbased I would prefer to do it in VR.

Participant #5
How did you experience the environment?

What do you like about the environment?

The trees and the differences in height of the terrain.

Would this environment be a place where you would discuss your health?

Yes, nice place.

Would you prefer sitting down, standing or walking around during the conversation?

Sitting down. That is easier.

What is your opinion about the forest environment?

It looks a little bit like a video game.

Questions for comparison of prototypes

Which prototype do you prefer? Why?

For such a conversation 2D is the easiest. For a longer conversation it would be VR. Because then you have more the experience that you are part of the conversation instead of feeling like answering some questions.

Participant #6

What is your opinion about the beach component in this environment?

Not really nice. A little bit boring. The grey walls.

What is your opinion about the couch in this environment?

Looks a little bit far away.

What is your opinion on the difference between the 2D and VR protoypes?

It is cooler because it feels more real.

Participant #7

What do you like about the environment?

The background in the distance. I would want to see more of it.

What do you dislike about the environment?

The walls of the room.

Would this environment be a place where you would discuss your health?

Yes, there is privacy and it is a calm environment.

Would you prefer sitting down, standing or walking around during the conversation?

Sitting down.

Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Outside. But not with other people walking around.

What is your opinion about the beach component in this environment?

Calming, you can focus on the agents.

What is your opinion on the difference between the 2D and VR protoypes?

In VR is way nice. You have more 3D. You can see more beach and you are more seated in the environment. You get a better feeling of sitting at the beach. Because of the sound and the visual you have more of the experience.

Study C

Participant #3

How did you experience the environment?

Was looking fine. Is a little bit weird that you are in a sort of room. No door or window. Sound and View are fine and give calm and relaxed atmosphere.

What is your opinion about the couch in this environment?

I do not see the added value.

What is your opinion about the table in this environment?

With answering on the table it is more clear and is easier to select.

What is your opinion about the chairs in this environment?

Third chairs makes me wonder if there is someone else coming,

Would you prefer the conversation takes place indoor or outdoor in the VR environment?

Deeper conversations are better in a room because it gives more privacy. I do not have a particular preference,

Which prototype do you prefer? Why?

The forest for the looks and feeling. For the interaction and brightness the beach. Overall the forest wins.

What is your opinion about the couch, table and chairs?

A table would be nice for clarity and interaction.

Sound of the sea and birds in the forest are soothing.

Participant #4

What is your opinion about the beach component in this environment?

I enjoyed it. The sounds and the looking far away.

Which prototype do you prefer? Why?

The beach. It is more calming. The sounds and everything are nice. More focused while still being able to look outside over the sea.

Do you prefer the inside or outside conversation? Why?

This feels more safe because it is indoors.

What is your opinion about the couch, table and chairs?

It gives more the feeling of regular conversation. More business like environment because of the table, couch and chairs.

Participant #5

Which prototype do you prefer? Why?

> The forest. It is more relaxed mainly because of the sounds.

Do you prefer the inside or outside conversation? Why?

> If you use VR I would do it that you do not have a room so outside because otherwise you miss the VR aspect.

What is your opinion about the couch, table and chairs?

I prefer the environment in the forest so no couch, table or chairs. Maybe something else could work like a little cabin in the background. Chairs from the forest are less distracting,

Participant #6

What is your opinion about the forest environment?

Nice. Better than the beach. Not the grey walls and a nice option to look around.

Which prototype do you prefer? Why?

The forest because you can see more.

Do you prefer the inside or outside conversation? Why?

Outside because there is nobody around. So in the open is fine.

What is your opinion about the couch, table and chairs?

The table is nice because talking while seated at the table is better. Couch is not needed. Chairs of the beach are nicer.

Participant #7

What is your opinion about the forest environment?

It was nice. More spacious. A lot to see and also calming but in a different way.

Do you prefer the inside or outside conversation? Why?

That is difficult. The environment of the forest but I prefer the sound of the beach. Outside because of nature, more freedom to talk.

What is your opinion about the couch, table and chairs?

The table create a sort of distance and serious feeling. I would prefer to have no table, a couch would be nice but maybe a little bit weird in the forest. I prefer the blue chairs.