Opportunities and Challenges in Using Virtual Reality to Improve Cognitive Functioning of the Elderly

by

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

MASTER OF SCIENCE

Department of Physiology & Pathophysiology

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Winnipeg

Abstract

Over the past decade, researchers have utilized novel technologies to improve the lives of the elderly population. Virtual Reality (VR) is among the most promising platforms which could be used to help the elderly to stay cognitively active; However, the extent to which this population is willing to seek out and engage in VR activities remains unclear. In this document we have discussed our two studies regarding VR and seniors. Our first study is a pilot project including three senior residents of Winnipeg. In this study, we assessed the impact of VR game name “DoVille” on cognitive capacities of the elderly. We designed a two-week procedure with 20 minutes VR sessions per day. While the comparison of pre-DoVille and post-DoVille test scores were statistically insignificant, we have gained valuable information about the feasibility and possible challenges of similar projects in the future. Among these issues we have discussed the eligibility criteria, VR sessions’ setting and length of training sessions for the seniors. The second study is a survey project assessing the attitudes of the elderly toward VR during the COVID-19 pandemic. All senior residents of Manitoba between the ages of 65 and 90 were eligible to participate in the study. The survey was administered online and by phone and 103 individuals responded to our questionnaire. Our results suggest that a large proportion of elderly individuals have become interested in VR technology as a result of the COVID-19 pandemic. We developed two models for VR use based on the responses. Our model of VR use for communication/interaction could account for approximately 50% of variance in interest levels in VR and our model of VR use for cognitive benefits accounted for 35% of variance. These models included variables such as previous experience with technology, age and gender. In conclusion, these two studies provide us with a better understanding of the elderly’s interest in technology and how we could implement new VR interventions for them in the future.

Acknowledgements

I wish to express my deepest gratitude to my supervisor, Dr. Mandana Modirrousta, for her patience and continual support along the way. I recognize my committee members - Dr. Tabrez Siddiqui and Dr. Ji Hyun Ko – for their flexibility and feedback over the past two years. I am equally indebted to Dr. Bruce Bolster whose humor, guidance and wise words will remain with me for the rest of my career.

Special thanks must be paid to Dr. Brian O'Connor for his incredible patience and advice in wake of my statistics questions and concerns.

I also acknowledge the profound role of my lab mates and research assistants. This includes our research coordinator, Benjamin Meek and my research assistant, Caroline Kehrer, who dedicated time to assisting me in this project.

Staff, management and residents at Brightwater Senior Living of Tuxedo and Carriage House North – Thank you all for making this study possible.

My amazing research participants – It has been an honour and privilege working with you. I truly enjoyed spending time with you.

My entire family – Thank for your love and support. I would have lost my sanity If it weren't for your support during my time in graduate school.

Lastly, I want to thank Project Whitecard Inc. and Mitacs Inc. for the internship opportunity. I learned significantly more than I expected over the internship period.

Dedication

In memory of my grandfather, who I wish could be here to see me now.

Preface

This research was the result of collaboration between researchers at University of Manitoba and Project Whitecard Inc. Both projects listed on this document were funded by Mitacs Inc.

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Abbreviations

2D	2-dimensional
3D	3-dimensional
AD	Alzheimer's Disease
aHPC	Anterior hippocampus
BAI	Beck Anxiety Inventory
BDI	Beck Depression Inventory
CAVE	Cave Automatic Virtual Environment
CCT	Computer-based Cognitive Training
DG	Dentate Gyrus
DLPFC	Dorsolateral Prefrontal Cortex
EEG	Electroencephalograms
TAM	Technology Acceptance Model
FMS	Fast Motion Sickness
fMRI	Functional Magnetic Resonance Imaging
HMD	Head-mounted Displays
LPC	Left Prefrontal Cortex
MTL	Medial Temporal Lobe
MCI	Mild Cognitive Impairment
MoCA	Montreal Cognitive Assessment
PTSD	Post-traumatic Stress Disorder
pHPC	Posterior hippocampus
SPMT	Scenery Picture Memory Test
SSQ	Simulator Sickness Questionnaire
TMT	Trial Making Test
UTAT	Unified Theory of Acceptance and Use of Technology
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
VBM	Voxel based Morphometry
PEU	Perceived Ease of Use
PU	Perceived Usefulness

Section 1. Pilot Study

Assessing the Impact of an Immersive VR Gaming Experience on Navigation Ability and Spatial Cognition in an Elderly Population

1.1. Introduction

Over the past decade, there has been an interest in using Computer-based Cognitive Training (CCT) methods (Kueider et al. 2012; Lampit et al. 2014). These training methods provide adjustable training content and easy access for individuals, making it an optimal choice for cognitive training (Jak et al. 2013). Most of these training methods or games have multiple assessment components including problem solving, attention and memory (Jak et al. 2013). Some studies have demonstrated improvements in cognitive tasks after utilizing these interventions for healthy older population (Chiu et al. 2017); However, there are certain limitations in research using CCT. For instance, some of the studies did not have an appropriate control group (see Johansson & Tornmalm 2012) or long term follow ups after training (see Belluci, Glaberman & Haslam 2002). Recently, ten Brinke & colleagues (2020) have assessed the effect of a combination of CCT and exercise on cognitive capacities of the elderly. They concluded that eight weeks of CCT could improve the executive functions of the elderly. They have also added that combining CCT with a round of exercise prior to the CCT could expand the cognitive benefits of the CCT intervention for healthy elders. Considering the current literature in the benefits of CCT, we still need more research to determine the efficacy of different CCTs for the elderly

1.1.1. Video Games

The newer category of cognitive training tools is generally referred to as videogame-based cognitive training tools. Similar to Computerized Cognitive training, video games target cognitive domains such as attention, memory and visuospatial skills. The differentiating factors in using video games are the adaptability of the games and possibility of utilizing platforms other than computers. Video games used for cognitive training in previous research could be categorized into two groups: 1) commercial games 2) games specially designed for cognitive training. Commercial games are not designed with the goal for any cognitive benefits, but to entertain the player. For example, one study has used “Super Mario Bros” and “Angry Birds” games to assess the benefits of 2-dimensional and 3-dimensional video games on hippocampal associated behaviors such as spatial memory (Clemenson & Stark 2015). Games which are designed to for cognitive enhancement would allow certain degree of flexibility. In consultation with cognitive neuroscientists, game developers could design video games which target a specific domain of cognitive abilities. For instance, Coutrot & Coleagues (2018) designed a mobile video game to specifically assess spatial navigation. The game became available worldwide and more than 558,000 individuals participated in the project. Another example is a category of strategy games which have shown promising results for improvement of executive functioning (Basak et al. 2008). Providing rewards for the desired behavior is among the common components typically included in video games to not only to provide feedback, but also to motivate the player to continue playing (Corbalan, Kester & Van Merrieboer 2009). Feedback could be provided throughout the game or as an overall summary once the player finishes each level.

While 2-dimensional (2D) and 3-dimensional (3D) video games can both be utilized, it appears that 3D games might be superior. In a study done by Clemenson & Stark (2015), the authors compared the effects of playing Super Mario 3D world (3D) and Angry Birds (2D) for two weeks. Individuals in the 3D group showed improved mnemonic discrimination ability and improvements in virtual water maze task.

Similar to studies using computer-based cognitive training, there are limitations to the use of using video games for cognitive enhancement. Firstly, not all of these studies have included a control group to eliminate confounding variables. Secondly, there is a pronounced variation in training time between different studies. Theses difference could be either the amount of training time per session or the overall training time based on the length of the study. Thirdly, it is not clear whether the benefits gained from video game intervention would transfer to real-world capabilities. Not all studies assess the targeted cognitive domains before and after training in a real-world environment (Dresler et al. 2013). Lastly, conflict of interest could become a critical issue as most commercially available video games are solely designed to entertain and increase their sale.

1.1.2. Spatial Navigation

Spatial navigation is the process by which organisms choose a path and then travel to their destination through that path (Gallistel 1993). Different animals utilize innate strategies which they have developed during their evolution. Some insect such as ants rely on a mechanism called “path integration”, using navigation vectors to determine the route to the nest. Some other species rely on the earth's magnetic field. For instance, sea turtles and salmon use earth's magnetic field for natal homing (Lohmann 2008). Research has indicated that humans and rats utilize more developed systems called "map-based navigation" (Tolman et al. 1946; Tolman 1948). In map-based navigation, the animal memorizes the layout of the environment. In the route-based navigation, the animal stores the sequence of turn vectors at each of the landmarks. In another classification, we divide the navigational systems into two categories: 1) Egocentric 2) Allocentric. Egocentric (body-centered) navigation relies on the body position and directions of turns to reach the destination (Burgess 2006, 2008). Allocentric navigation (world-centered) involves utilizing environmental cues and landmarks in relation to the navigator's position to reach a specific destination (Norman & McDonald 2003; Aeleo & Rondi-Reig, 2007; Burgess 2006). Studies have indicated that allocentric navigational strategies mainly involve the activation of the hippocampus (Eichenbaum 2015, Garrud et al. 1982). The underlying region of activation is more complicated for egocentric navigation; While simple egocentric navigations mainly involve dorsal striatum, more complicated tasks such as sequential path finding would require the activation of other areas including hippocampus and rostrolateral prefrontal cortex too (Morris et al. 2001; Byrne 2007)

Humans' preference for the two navigational strategies (egocentric and allocentric) is not stable across the lifespan. Studies have indicated a delayed development of allocentric navigational strategies, when compared to egocentric ones (Acredolo 1978; Piaget & Inhelder 1948). Early signs of egocentric strategies have been found in children as young as 6 months old (Piaget & Inhelder 1948); However, the earliest evidence of navigation strategies based on location and landmarks has been observed at around 36 months old (Nardini et al. 2006). It seems that the learning process continues until the ages of 8-10 years old (Leplow et al. 2003). Researchers have suggested two possible explanations for the delayed development of world-centered strategies. The first one is the underdeveloped hippocampus in children. Since allocentric navigation heavily relies on spatial cues and landmarks, it requires a fully mature hippocampus to have the capacity to process the navigational task. As a result, we could associate the poor performance of children on allocentric navigational tasks to the delayed state of hippocampal development (Newcombe & Huttenlocher 2000). For instance, previous research has shown that immature hippocampus would hinder child's ability to reorient using non-geometric features of an environment (Vieites et al. 2015) The second explanation has highlighted the role of walking and exploring the environment. Based on this explanation, children would start utilizing allocentric strategies when they start to walk and explore their environment (Newcombe & Learmonth 1999; Newcombe & Huttenlocher 2000)

Previous studies have also demonstrated an age-related decline in spatial navigation capacities (Moffat & Resnick 2002; Newman & Kaszniak 2000). Deterioration of these abilities is concurrent with age-related decline in medial temporal lobe volume. Neuroimaging studies have supported this assertion by demonstrating a decrease in hippocampal activity during spatial navigation tasks in older adults (Antononva et al. 2009; Moffat et al. 2006). Some studies have found a decline only in allocentric navigational strategies. However, other studies have indicated that individuals suffering from Alzheimer's Disease (AD) and Mild Cognitive Impairment (MCI) are susceptible to degradation of allocentric and egocentric strategies as they get older (Moffat & Resnick 2002; Moffat et al. 2006; Newman & Kaszniak 2000; Talimini & Gorree 2012). In addition to the change in the navigational strategies, elderly individuals tend to utilize significantly fewer shortcuts to reach their destination (Irving et al. 2013).

Sex differences in spatial navigation is one of the topics that is still debated among the researchers. Some studies have found that men outperform women in sequential navigational tasks (involving multiple locations and paths) (Picaardi et al 2014; Plalmiero et al. 2016). This performance difference might be explained by evidence of higher memory span of men in tasks with high visuospatial working memory load (Coluccia & Louse 2004; Picaardi et al 2008, 2013). Higher memory span might have led to the improvement of man's navigation when multiple locations are involved. There are also other studies finding no significant difference in performance in real world and virtual environment navigational tasks (Nori et al, 2015, 2018).

1.1.3. Episodic Memory

"Episodic Memory" is considered a type of declarative memory which contains the two critical dimensions of time and place of acquisition (Tulving 2002). Details of the place where an episodic memory is acquired is important. As a result, acquiring episodic memories requires a significant contribution of medial temporal lobe (MTL), especially regions such as hippocampus, parahippocampal area and entorhinal cortex (Zhisen et al. 2016) where cells such as grid cells and place cells are located. While grid cells fire at regular discrete locations to form hexagonal patterns tiling the environment (Fyhn 2004; Hafting et al. 2005), Place cells fire when the individual (or animal) enters a certain area of the environment (O'Keefe & Dostrovsky 1971) and every place cell is representative of a specific location in the environment. Another region which has significant input for encoding the new information is the left prefrontal cortex (LPC) (Tulving 2002). Unlike acquisition of episodic memories where MTL and LPC make the most significant contributions, during retrieval the critical region is the right prefrontal cortex (Tulving 2002).

Retrieving episodic memories has been previously explained by "mental-time-travel" hypothesis (Tulving 2005; Tulving 1985). According to this theory, in order to retrieve an episodic memory, individual would travel back to that specific time to reexperience the event. The more recent model has utilized a cone-shape structure to highlight the diminishing precision of memories relative to the time they were encoded (Roberts & Feeney 2009). The length of the cone represents the time and it elongates as the individual gets older (Spreng & Levine 2006). The width of the cone represents the amount of detail available at a certain point in time.

According to" Dual Process Hypothesis", event segmentation process and narrative binding process will act as complementary elements of experienced memories (Nazim 2016). The event segmentation portion mainly involves identifying boundaries of events, determining when one event has finished and the other one has started (Zacks et al. 2007). This process will form the event memory, a collection of time slices with maximum amount of change in sensory features. For example, each of these time slices will have maximal change in features such as movement, sound and colour. The narrative binding process involves analyzing and organizing events and finding a goal to connect the events together as a story. These processes work together in the formation of episodic memories (Nazim 2016). Unlike event memories which would be easily forgotten (unless they are connected to other events as a part of a narrative), episodic memories could be retained for longer periods of time. Another difference between these two types of memory is the level of accuracy. While event memories are represented as highly accurate visual images, episodic memories are narratives with relatively low accuracy (Marsh & Tverski 2004); However, event memories are not immune to modification. Previous studies have shown that techniques such as suggestive dream interpretation, guided meditation and exposure to doctored photographs could create false memorie of the event in the past (Lindsey et al. 2004; Loftus 2003). Neuroimaging data have depicted different underlying brain activation patterns for event memory and episodic recall. It appears that episodic memory mainly involves occipital, parietal, prefrontal and medial-temporal cortex (Buckner & Carroll 2007;

Spreng et al. 2009). Encoding of event memories and segmentation process show networks of activation in extrastriate visual cortex and right posterior frontal cortex (Zacks et al. 2007)

1.1.4. Virtual Reality & Spatial Navigation

Virtual Reality (VR) has become the newest addition to the platforms available for cognitive training. VR has multiple components which make it a superior option comparing to the other platforms. First, VR has the capacity to create a stronger sense of "presence" for the player (Banos et al. 2000). In other words, playing in a virtual environment has the most resemblance to being in the real world. This is beneficial as research has shown that individuals are more likely to act more realistically if they feel the environment is real. Second, VR allows us to combine different sensory stimulations such as sight and touch. This characteristic of VR has significant importance in studies of body-transfer illusion where visual and tactile feedbacks gives the individual a false sense of ownership over their virtual body. Third, it would enable researcher so design experiments that would be unethical in the real world. For example, Cheetham and colleagues (2009) have conducted a replication of Milgram Obedience experiment in the virtual environment. They have utilized fMRI to detect any activation in cingulate cortex and insula while participants were in the virtual environment. Lastly, virtual reality could be a convenient option for individuals with mobility restrictions. Elderly population can use portable VR headset for exploring a new environment as an alternative to physically moving. In addition, researcher could use portable VR headsets to include participants who have physical or mobility limitation and cannot come to the research lab.

1.1.5. Video Games & Brain

Researchers have investigated the effects of cognitive training on the brain. An early study by Kuhn and colleagues (2011) found a higher left ventral striatum volume in gamers who play more than 9 hours per week. Another study attempted to differentiate the effect of different genres of gaming on the grey matter volume in the brain. They concluded that logic/puzzle and platform games were positively associated with entorhinal gray matter volume, whereas action role-playing games were negatively associated with entorhinal gray matter volume. In addition, they concluded that this association is reflective neural plasticity of cognitive abilities such as navigation and visual attention (Kuhn & Gallinat 2014). One game that has been used multiple times to investigate the effects of video games is Super Mario 64. West and colleagues (2017) chose a sample of 55 to 75 years old adults and used Voxel Based Morphometry (VBM) technology to compare the grey matter volume in hippocampus before and after playing this game for six months. They found a significant increase in hippocampal volume in comparison to the control group. This increase is in line with similar studies using Super Mario for training younger adults (Clemenson & Stark 2015). In addition to an increased hippocampal volume, they also detected an increased growth of cerebellum in comparison to the control group.

1.1.6. Cybersickness

While VR has the potential to be one of the best cognitive training options, there are a number of issues that should be considered. The first issue is the possibility of experiencing "cybersickness". Cyber sickness typically happens if the sensory input from the VR system is overwhelms the player, leading to nausea and headache. There are multiple factors affecting the likelihood of experiencing cybersickness. Individual tolerance, screen resolution screen refresh time, and the nature of the VR task can all impact how likely an individual is to suffer from cybersickness.

Research has shown that longer exposure times are linked to increased likelihood of cybersickness (Moss et al. 2011); However, individual tolerance might result in various maximum tolerated exposure time. Another factor contributing to likelihood of suffering from cybersickness is sex. Previous research has indicted that females are more likely to experience cybersickness (Kim et al. 2005; Stanney 2003). The reasoning behind the sex difference is not clear yet but menstrual cycle (Clemes & Howarth 2005), stability of posture (Koslucher, Haaland & Stoffregen 2016) and different field of view (LaViola 2000) have been suggested as the possible factors leading to this difference.

Some studies have suggested that there are two main sensory conflicts responsible for the cybersickness. The first one is the conflict between the vestibular and visual signals and the other one is the conflict between semicircular canals and otoliths within the vestibular system (Lackner 2014; Reason 1978); However, no clear physiological pathway has been identified to fully explain these conflicts (Davis, Nesbitt & Nalivaiko 2014).

Researchers have attempted to prevent cybersickness by different methods including modification of the VR environment (Llorach, Evanss & Blat 2014) but it appears that adaptation to VR might happen after some time for some individuals. In order to assess the susceptibility of individuals to cybersickness and its associated symptoms, researcher could utilize the Simulator Sickness Questionnaire (SSQ) (Kennedy et al. 1993). The questionnaire consists of 16 symptoms and respondents should indicate if they have experienced any of these symptoms. They also indicate the severity of each symptom they have experienced. Since the development of this questionnaire, Keshavarz & Hecht (2011) have developed FMS (Fast Motion Sickness Scale) which can be administered during a user's exposure to virtual environment. FMS is a verbal scale and research has shown a high level of correlation between the score on this scale and SSQ (Keshavarz & Hecht 2011).

1.1.7. Understanding of Technological Concepts

The second issue regarding using VR with an elderly population one is a possible lack of understanding of technological concepts and absence of previous experience in using Virtual Reality. Previous studies have indicated that elderly are less likely to use personal computers and the internet or the World Wide Web (Pew & Van Hemel 2004). According to the theory of diffusion of innovations (Rogers 2003), elderly individuals are less likely to accept the use of new technologies in their life; However, they might adopt these technologies If they found them beneficial. For instance, any possible cognitive health or physical health improvements could increase the likelihood that older adults would be interested in using that technology. The challenge is to inform older individuals about the benefits as some of them are not aware of available devices and their benefits (Heinz et al. 2013). Researchers have formed focus groups to investigate the attitudes of the elderly and the challenges they face in using new technologies. For example, Vaportzis, Giatsi Clausen & Gow (2017) asked individuals between 65 and 76 about their attitude toward technology and specifically tablets. While some individuals talked about their health issues and the costs of such devices, others expressed their concerns about the lack of proper instructions and personal knowledge of technology. They showed their dissatisfaction with instructional guides, stating that these manuals have written in a way which is not easy for inexperienced individuals to follow and learn. They have also expressed their fear of feeling inadequate since they are not familiar with new technologies and devices. In another focus study (Heinz et al. 2013), older adults also indicated that they believe computers and technology are too complicated. Additionally, some individuals expressed their concern regarding the loss of social contact as a result of relying on technology too often.

Wang & Sun (2016) have a proposed a model named "Extended Technology Acceptance Model" (TAM) to indicate the key predictors of the intention of elderly individuals to play digital games. According to this model, there are three variables which could act as predictors of intention to play: 1) Perceived usefulness 2) Perceived ease of use 3) Narrative. Perceived usefulness is defined as the degree to which an individual (older adult) believes the digital game is beneficial for his/her physical and mental health. Perceived ease of use is defined as the extent to which an individual expects a digital game to be effortless. The third component, game narrative, is the storyline which the player will follow throughout the digital game. While all three of these factors could directly affect the intention to play digital games, perceived usefulness and perceived ease of use can have an indirect influence on the intention moderated by individual's attitude toward playing. An individual's gender and age will also be factors modulating the effect of perceived usefulness and perceived ease of use on one's intention to play. Previous experience of playing digital games will also be modulating factor in a similar vein. In addition, their model confirmed two other relationships: 1) a positive relationship between physical condition and intention to play and 2) a negative relationship between social interaction and intention.

1.1.8. Distracting Environment

The last issue with using VR environment for the elderly is the possibility of overwhelming attentional capacity. This problem appears to negatively impact spatial learning for older adults. Previous research has indicted that crowded environments in VR or environments with too many distractions negatively affect individual's ability to process the relevant cues and inhibit the irrelevant ones (D'Esposito et al. 2005; Merriman et al. 2018). Older adults have age-related limitations of attentional capacity and providing too much distraction and irrelevant information decreases the likelihood that individual would pay be able to extract relevant information.

Current Study

In this study, we attempt to assess the effects of VR training on individuals' performance in a real-world task called the "object-in-place memory task". This task assesses the episodic process that relies both on a mental map of your surroundings, and a mental record of your interactions with these objects in time. Previous research has indicated that episodic processes are dependent on the hippocampus and anatomically connected brain structures for successful performance (Barker & Warburton 2015).

Rationale:

This is the first study which has utilized non-virtual reality to assess the effects of VR training on individuals' performance. The results of our pilot study can potentially lead to development of effective virtual reality interventions and full study designs. Effective intervention paradigms would have great impact on cognitive rehabilitation in patients with cognitive impairment and could be incorporated as part of the care and rehabilitation plan for those individuals.

Hypothesis and Objectives

Hypothesis: Individuals who participate in the virtual reality training will show improvement in their spatial navigation abilities and scene memory comparing to those who do not.

Specific Objectives:

1. Determining whether regular exposure to DoVille improves spatial memory (in comparison to object and temporal memory) in older adults, as tested using object-in-place task in a non-VR environment.

1.2. Materials and Methods:

1.2.1. Participants:

The Research Ethics Board at the University of Manitoba approved this study. Informed consent forms can be found in Appendix A. Interested seniors were recruited through multiple ways, including presentation at two senior residences, online advertisement and printed flyers at St. Boniface Hospital. The participants were three elderly (2 females, 1 male) living in a senior residence complex. Participants had normal or corrected to normal vision and were screened for major psychiatric or neurological disorders. Additionally, they were all cognitively intact based on Montreal Cognitive Assessment (MoCA).

1.2.2. Design:

Following the initial cognitive screening using Montreal Cognitive Assessment (MoCA), participants responded to a series of neuropsychological testing and one real world task. On day (1), they responded to the following tests in order: 1) Beck Anxiety Inventory (BAI) 2) Beck Depression Inventory (BDI) 3) Rey-Osterrieth Complex Figure Test (Copy) 4) Digit Span Test 5) Rey-Osterrieth Complex Figure Test (Immediate) 6) Story recall immediate 7) Scenery

Picture Memory Test (Immediate) 8) Corsi Block Tapping 9) Rey-Osterrieth Complex Figure Test (Delayed) 10) Paired Associate Immediate 11) Story Recall Delayed 12) Scenery Picture Memory Test (Delayed) 13) Trail Making A & B 14) Paired associated delayed. On the second day, participants completed object-in-place memory task.

Following the baseline testing, participants completed VR training using an Oculus Go VR system. Training consisted of 10 individual training sessions (20 minutes per weekday for two consecutive weeks) during which participants played the DoVille VR game.

After 10 sessions of VR training, participants completed the same assessments as pre-training (MoCA and 14 assessments on day (13), Object-in-place task on day (14)),

1.2.3. Measures:

Montreal Cognitive Assessment MoCA). The MOCA is a one page 30-point test administered in 10 minutes (Nasreddine et al. 2005). The test is commonly used to assess overall cognitive capacities as it covers multiple domains including visuospatial/Executive, memory, attention and language. The test was administered at the beginning of the experiment as a screening tool to exclude individuals with below normal cognitive abilities. The same test was administered at the end of the experiment to detect any significant changes in the score.

Beck Anxiety Inventory. The Beck Anxiety Inventory (BAI) is a self-report intended to assess the somatic symptoms of anxiety (Beck et al. 1988). The inventory includes 21 items and respondents indicate how much they have been bothered by each symptom using a 4-point Likert scale (0 *(not at all)* to 3 *(severely)*)

Beck Depression Inventory. The Beck Depression Inventory (BDI-II) is a self-report designed to measure depression symptoms and their severity for individuals who are 13 years old or older (Beck, Steer & Brown 1996). The inventory includes 21 items and respondents indicate degree of severity each symptom a 4 on a Likert scale ranging from 0 *(not at all) to* 3 *(extreme form of a symptom).*

Digit Span Test. In this assessment, the examiner reads a string of digits of increasing length. The subject is instructed to repeat digits in the same order (Forward) and in reverse

(Backward). Sets of digits were identical and retrieved from Wechsler memory scale (Wechsler 1945). While forward spans assess individuals' attention and working memory, reverse spans are designed to evaluate the capacity of the individual to restructure the sequences (spans). Since this restructuring requires an active manipulation of the briefly maintained contents of the working memory (sequences), reverse spans will assess central executive function of the individual.

Rey-Osterrieth Complex Figure Test. The task was developed by Rey (1941) and Osterrieth (1944) and it assesses multiple cognitive domains including planning, organizational skills, problem solving strategies and episodic memory (Park et al. 2006). The test was administered in 3 stages. At the first exposure to the figure, participants were instructed to copy the image as accurately as they can (Copy). After 5 minutes, participants were instructed to draw the figure from memory (Immediate Recall). After 20 minutes, participants were instructed to draw the figure again (Delayed Recall). Drawings were scored according to the guidelines in which 18 units in the figure are scored from 0 to 2 (Osterrieth 1944).

Story Recall. In this task, examiner read a short story (one paragraph) aloud and asked the participant to tell the examiner as many details as they remember from the paragraph. The short story (paragraph) was retrieved from Wechsler Memory Scale (Wechsler 1945). Participants were asked about the story twice: 1) Immediately after listening to the story (Immediate) 2) 20 minutes after listening to the story (Recall). The paragraph was divided into multiple segments and participants were scored based on the number of segments they successfully recalled.

Scene Picture Memory Test. The Scene Picture Memory Test (SPMT) is designed to assess the amount of visual information individuals can remember (Takechi & Dodge 2010). SPMT uses a line drawing scenery picture which includes 23 objects. Participants studied the picture for one minute. After the encoding period, examiner asked the participant to recall as many objects as they can (Immediate Recall). After 20 minutes, participants were asked to recall the as many items as the can again (Delayed Recall). The number of items recalled was considered as the participant's score on the task.

Corsi Block Tapping. Corsi block tapping is commonly used to assess visuospatial short term and working memory (Kessels et al. 2000). The board and cubes were set up according to the standards set by Kessels & Colleagues (2000). The examiner tapped a sequence of blocks and the participant was instructed to mimic the tapping sequence. Participants were provided with two trials for each sequences of the same length. If the participant responded correctly to at least one trail, the next two trials were administered. Participants were examined on Forward and Backward sequences and sequences used in trials were identical to standardized studies (Kessels et al. 2000, 2008). Block span and total score were calculated separately for forward and backward sequence.

Paired Associate Test. The Paired Associate test is designed to assess explicit episodic performance of individuals. During this task, examiner presented the participants with pairs of words. Afterwards, examiner read one word of each pair and asked the participant for the paired word. Words used in the study were all retrieved from Wechsler Memory Scale Verbal Paired Associated (Wechsler 1945). Participants were asked about the paired word twice: 1) Immediately after listening to the list of words (Immediate) 2) 20 minutes after listening to the list (Recall).

Trail Making A & B. Trial Making Test (TMT) is a measure of speed, mental flexibility and attention (Lezak 2004). Participants were asked to connect 25 encircled numbers randomly arranged on a page in correct order (Part A) and 25 encircled numbers and letters in alternating manner (Part B). Two scores were recorded for each part: 1) Time required for completion 2) number of errors.

Object-in-place Memory Task. This task assesses the episodic processes that relies both on a mental map of your surroundings, and a mental record of your interactions with these objects in time. Previous research has indicated that these processes are dependent on the hippocampus and anatomically connected brain structures for successful performance (Barker & Warburton 2015). Ten small tables were arranged in two parallel rows (five tables in each row), with a larger, oval table at the rear wall. On each of the small tables, nine circles were drawn in a 3x3 grid. Prior to testing, five objects were placed in the back right-hand corner of each of the ten small tables. Half of the tables contained objects belonging to a single category, while the other half contained a collection of random objects.

The task consists of a learning phase and a testing phase. Prior to the learning phase, participants were instructed to pay careful attention to which objects were on which tables, as well as the order in which the tables were indicated by the experimenter. During the learning phase, the experimenter pointed to each table, one-by-one, in a pre-determined order. Each time a table was indicated, participants were given ten seconds to arrange the objects on that table in whichever orientation they pleased, provided that each object occupied its own unique drawn circle within the 3x3 grid. Once all ten tables were arranged, the participants were asked to exit the room for approximately one minute. During this time, the experimenter removed one pre-determined object from each of the ten tables. The testing phase began immediately upon the participant re-entering the room, and consisted of an ‘object’ memory condition, a ‘spatial’ memory condition, and a ‘temporal’ memory condition. In the ‘object’ condition, participants were presented with pairs of two objects (a ‘target’ object and a distractor object) and were asked which of the two objects was the one that the experimenter removed from a table. In the ‘spatial’ condition, participants were shown the target object, and asked to choose which of two tables that object had been taken from. In the ‘temporal’ condition, two tables were indicated to the participants, who were asked to decide which table they had arranged first in the learning phase. After each learning phase, all three memory types (object, spatial, and temporal) were tested. For all three conditions, participants will be given ten seconds to give a response.

1.2.4. Virtual Training Game – DoVille

During 10 training sessions, participant played a Virtual Reality Game called “Doville”. which was designed by the Mitacs Inc. Partner-Project WhiteCard. All participants played the game on a standard Oculus Go standalone headset. These headsets were developed by Facebook Technologies and operated on an Android 7.1.2 system (Panel type: Single Fast-Switch LCD 2560x1440; Audio: Integrated, in strap; CPU: Qualcomm Snapdragon 821; GPU: Adreno 530; Lens Distance: Fixed). Rotating chairs were provided to allow users to freely rotate during the VR sessions.

Participants were allowed to explore a virtual city with multiple landmarks including but not limited to a beach, a hotel, an amusement park, a coffee shop and a bowling alley. They were also allowed to interact with the environment by picking up objects and listening to virtual inhabitants of this city. In order to guide each individual during the game, VR headsets were synced with a tablet, allowing the research assistant to observe the participants actions in the VR environment. All participants were introduced to the game in the same following order:

On the first day, each individual completed a tutorial to familiarize himself/herself with the VR environment and the controller. During the second session, participants were allowed to choose between navigating freely in the environment or following a storyline while exploring the environment. Following the storyline required the individuals to use the clues provided in the game to find a stolen piece of jewelry and arrest the thief. Appropriate signs and hints were placed in the game to assist them throughout the story. For the remaining training sessions (sessions 3-10), participants had the opportunity to focus on the storyline, follow the thief using the provided clues and arrest the thief.

1.3. Results

All statistical analyses were performed using IBM SPSS 20 software. Considering our small sample size (n=3) and the paired dependent measures (pre-post), we decided to carry out Wilcoxon signed ranks test to compare available pre- and post- scores. This test is a non-parametric equivalent of student t-test, commonly used to compare 2 two related groups of data (Frey 2018). SPSS software calculated the differences between pre and post-training scores, ranked theses scores and assigned the sign of the difference. The sum of the positive and negative ranks was calculated to determine the overall T statistic. Medians, test statistics, z-scores, probability values and effect sizes are summarized in Table 1. Wilcoxon signed ranks test did not reach statistical significance for any of the tests administered before and after VR sessions. The effect sizes for Rey-Osterrieth test-copy (r = .66), Rey-Osterrieth test-immediate (r = .65), Rey-Osterrieth test-delayed (r = .65), corsi Block tapping forward (r = .58) and its total score (r = .58), corsi block tapping backward (r = .58) and its total score (r = .65), trail making A time (r = .65) were found to exceed Cohen's (1988) convention for medium effect (d = .50)

1.4. Discussion

This study is the first to use non-VR assessments to evaluate the effect of VR on cognitive abilities of the elderly. As in previous studies done in this area, we included cognitive assessments before and after VR training. However; those studies relied on a limited number of tests to establish baseline and post-training scores. For instance, Clemenson & Stark (2015) relied on the Mnemonic Similarity task (MST) scores to compare cognitive capacities at baseline and post VR. We included more cognitive tests to cover different cognitive domains including working memory, episodic memory and scene memory. Since previous studies such as the one done by West & Colleages (2017) have utilized Voxel Based Morphometry (VBM) to assess the amount of gray matter before and after VR training, it would be optimal if future large scale studies include brain imaging in their study. Additionally, adding electroencephalograms (EEG) during participants' VR experience would add a distinct understanding of process and changes in the brain. It is worth noting that adding these measures to our study would not have yielded meaningful results as our sample was very small.

Even though our limited data has not captured a statistically significant benefit of VR intervention for cognitive function (spatial navigation and scene memory), we have acquired more information to design larger scale studies in the future. Here we discuss three key dimensions of our pilot study including feasibility, management and scientific design. Regarding the recruitment and retention rate in our study, we faced a lack of interest from majority of seniors living in the participating locations. Some individuals expressed their interest in learning about VR technology, but they were not interested in participating in the project. They provided multiple reasons including but not limited to familial commitments, lack of sufficient time and physical limitations. At the beginning of the study, we used a MoCA score of 26 as the eligibility criteria for participation. In response to low number of eligible participants, we reviewed the literature and realized that using 26 as the cut-off score may not be the best option. Borland and colleagues (2017) have developed a chart to determine MoCA cut-off scores based on age and education level of individuals. According to this table, as the age increases, the cut off will be lower. Additionally, the cut off increases as individual's education level increases.
In order to consider these two factors, we believe future studies with elderly should use these cut-offs rather than traditional score of $\geq$26. Using 26 might be too restrictive, resulting in exclusion of many potentially eligible participants.

Since the study was conducted at seniors' residences, we encountered a delay in starting the project at these locations. It is important that future projects initiate their discussion with potential participating locations several months in advance to ensure we reach an approval at the desired time. It is crucial to communicate with location's personnel and management to avoid any conflict of schedules with their ongoing events. Regarding the logistical issues, it would be optimal if participating locations provide a quiet area with enough space for at least three people. Since we were provided with a large shared area for our project, there were multiple distractions throughout the sessions, limiting the participant's focus on responding to the test or focusing on their VR tasks.

The two-week VR procedure with 20 minutes on each weekday appears to be safe for seniors. None of the participating individuals complained about the length of sessions or feeling uncomfortable because of VR. The DoVille VR game seems to have sufficient entertaining component to keep them busy and exploring the VR environment. Unlike previous games such as Super Mario 64 used for seniors (West et al. 2017), we did not observe a steep learning curve. Participants rapidly learned how to use their controller and interact with the DoVille environment. It appears that gameplay and detailed instructions were the main contributor to the different learning speed. DoVille included step by step tutorials and detailed instructions throughout the game. Additionally, developers of DoVille attempted to design the game in a way that it would be comfortable and simple for navigation. It is also worth noting that DoVille and game such as Super Mario 64 are designed with different goals in mind. While Super Mario 64 is designed to entertain players who are mostly young, DoVille was designed for seniors who are looking for a game that might be beneficial to their cognitive functioning. Since DoVille was designed to improve cognitive capacities (including memory), designers had incorporated some components of encoding and retrieval of memories using the clues for catching the thief of the jewellery . These components are limited in Super Mario 64. Even though we did not find statistically significant effect of this game, it appears that it would be a suitable candidate for future studies in this area. Monitoring participant's gameplay throughout the session is also a component which is worth doing in t future studies, as it is helpful when participants ask questions about the VR environment which they are looking at. For pre- and post- measures, there were no significant issues to report. Participants understood the assessments and responded accordingly.

While most tests in our study resulted in medium or larger size effects, we should interpret them with caution. Since we have very small sample size (*N*=3), our effect size could not be interpreted as the magnitude of the effect of our VR intervention on individuals' cognitive capacity. It is possible that theses estimates would be a reflection of our small sample size in the study and not the target population. Even adding a few participants might have dramatic effects on these values as they are strongly dependent on the size of our sample.

Since all participants in this pilot study were from similar senior residences, we can not extract the factors that contribute to individual differences. Future large-scale studies should consider including different locations and include individuals with having different socioeconomic status.

In conclusion, this pilot study has yielded valuable information on how to implement a VR procedure for future large-scale studies. Our 2-week procedure appeared to be feasible; However, future studies could benefit from: 1) Utilizing a less restrictive eligibility criteria 2) Including more participating locations 3) Ensuring researchers have a quiet designated space at each location.

Table 1

Results of Wilcoxon signed-rank test comparing the test scores before and after VR training

Test	Pre-Test			Post-Test			*T*	*z*	*p*	*r*
	Mdn	*Min*	*Max*	*Mdn*	*Min*	*Max*				
Rey-Osterrieth Copy	31	30	33	33	33	35	6	-1.633	.102	-.66
Rey-Osterrieth Immediate	18	16	19	25	24	28	6	-1.604	.109	-.65
Rey-Osterrieth Delayed	15	14	16	25	22	29	6	-1.604	.109	-.65
Digit Span Forward	6	5	7	5	4	8	1	-.447	.655	-0.18
Digit Span Backward	4	4	5	4	4	5	0	0	1.000	0
Story Recall Immediate	8	6	11	8	8	9	1.5	0	1.000	0
Story Recall Delayed	6	4	7	3	3	8	1.5	-.816	.414	0.33
Scene Recall Immediate	14	14	19	17	16	18	5	-1.069	.285	0.43

Table 1 (Continued)

Test	Pre-Test			Post-Test			*T*	*z*	*p*	*r*
	Mdn	*Min*	*Max*	*Mdn*	*Min*	*Max*				
Scene Recall Delayed	14	13	16	18	12	18	5	-1.069	.285	-.043
Forward Corsi Block Tapping	6	5	6	7	5	7	3	-1.414	.157	-0.58
Forward Corsi Block Tapping (Total Score)	60	40	60	77	40	77	3	-1.414	.157	-0.58
Backward Corsi Block Tapping	5	5	6	6	6	6	3	-1.414	.157	-0.58
Backward Corsi Block Tapping (Total Score)	3	3	6	56	54	70	6	-1.604	.109	-.65
Paired Associate - Immediate	6	4	8	6	6	8	2	-.447	.655	-0.18
Paired Associate - Delayed	6	6	6	6	6	7	1	-1.000	.317	-.40
Trail Making A (Seconds)	48	36	52	40	33	45	0	-1.604	.109	-.65

Table 1 (Continued)

Test	Pre-Test			Post-Test			*T*	*z*	*p*	*r*
	Mdn	*Min*	*Max*	*Mdn*	*Min*	*Max*				
Trail Making A (Lines)	24	24	72	24	23	24	0	-1.000	.317	-0.40
Trail Making B (Seconds)	111	85	141	90	90	130	1	-1.069	.285	-0.43
Trail Making B (Lines)	24	24	24	23	20	24	0	-1.342	.500	-0.54
Object in Place Task - Object	10	10	10	10	10	10	0	1.000	1.00	-0.40
Object in Place Task - Spatial	8	8	10	10	8	10	1	-1.000	.317	-0.40
Object in Place Task - Temporal	5	3	7	6	4	8	2.25	-.816	.414	-0.33

Section 2. Survey

Attitudes of the elderly towards Virtual Reality gaming and socialization in relation to the COVID-19 Pandemic

2.1. Introduction

According to a recent publication by the United Nations, currently 12.5% of people are aged 60 years or older (World Health Organization, 2015). Even though there is an upward trend in internet usage and smartphone ownership among the elderly, they are still behind the curve when compared to the middle-aged individuals and teenagers (Davidson & Schimmele 2019). The use of novel and emerging technologies to improve the lives of the elderly population has become a topic of interest for researchers. Various platforms including tablets (Savulich et al. 2017) and cell phones (Coutrout et al. 2018) have been utilized to improve cognitive capacities of the elderly. For example, Savulich and colleagues (2017) have developed a novel memory game for iPad which could significantly improve episodic memory in patients suffering from cognitive impairments. In another study, Chan and colleagues (2016) have shown the effectiveness of using the iPad to improve episodic memory and processing speed. Promising results from these studies led investigators to use more interactive technologies such as Virtual Reality (VR).

VR systems provides a feeling of detachment from the real world and a sense of "being" in the virtual environment. This characteristic is referred to as "immersion", based on how VR systems have been categorized (Mujber, Szecsi & Hashmi 2004). Non-immersive, semi-immersive and fully immersive are the three main types of VR systems available for personal use. While low-immersion VR systems have lower levels of interaction and rely on a desktop computer, immersive systems provide a high level of interaction by relying on head mounted displays (HMD) or Cave automatic virtual environment (CAVE). CAVEs are cube shaped VR rooms where screens are projected on the walls, ceiling and floor (Kenyon & DeFanti 1995). Over the past few years, researchers have utilized this capacity to use VR for a variety of purposes including improving mnemonic discrimination ability, improving navigation in virtual water maze tasks and reducing social isolation (Khosravi, Rezvani & Wiewiora 2016; Clmeneson & Stark 2015; West et al. 2017). Previous research has introduced VR as a feasible option to reduce levels of depression and loneliness among seniors (O'Connor, Arizmendi &

Kaszniak 2014). Even though such usages of VR could be beneficial for the elderly, it is crucial to understand their level of interest in such technologies.

Previous research in technology acceptance has commonly relied on two powerful models: the Technology Acceptance model (TAM) (Davis 1989) and the Unified theory of acceptance and use of technology (UTAT) (Vankatesh, Morris & Davis 2003). These two models share two variables as important factors in explaining individual's intention to use technology: One is perceived ease of use (PEOU) and the second one is perceived usefulness (PU). The UTAT model has added modulating variables (such as age and experience) and new variables (facilitating conditions and social influence), allowing the model to explain up to 70% of intentions for using VR (Vankatesh, Morris & Davis 2003). A recent model of TAM (Vankatesh & Bala 2008) has emphasized the role of individual's experience and its modulatory effect on PEOU and PU. They have suggested that previous experience with a system would increase the effect of PEOU on PU as the user will be able to evaluate the usefulness of the technology based on their previous experiences. While new technologies could be beneficial for the elderly, it is important to consider issues and limitations within this population. Older adults may have sensory limitations which could prevent them from fully processing various dimensions of new technologies (Czaja & Lee 2006). These issues coupled with their fear of technology (Steele et al. 2009) creates challenges for implementation of new technologies for the elderly. Peek and colleagues (2014) identified recurring themes and factors which could have an impact on the acceptance of technology by older adults. They highlighted six different themes including concerns, expected benefits, social influence and characteristics of older adults. Each of these themes includes more specific factors which might contribute to the acceptance of technology. Other studies have emphasized concerns for elderly individuals regarding privacy issues, cost and negative personal health effects (Lorenzen-Hubber 2011, Steele et al. 2009).

Regarding the demographics such as age and gender, some studies have found mixed results (Fang et al. 2019; Peek 2014) while others have found specific preferences between genders. For instance, women commonly have higher levels of interest in using devices designed for support and health purposes, but men are more interested in communication and entertainment devices (Halmdienst; Radhuber & Winter-Ebmer 2019). In addition, authors of the same study have found decreased interest in communication and entertainment devices with an increase in the age of both men and women.

In a recent study by Syed-Abdul and colleagues (2019), the investigators assessed the acceptance and use of Virtual Reality (VR) technology by the elderly. They concluded that older people have a positive attitude toward VR technology and find it enjoyable. However, the extent to which elderly people are willing to seek out and engage in novel technologies such as VR remains unclear.

In the current survey, we have examined elderly individuals' attitude toward Virtual Reality in relation to the COVID-19 pandemic. Specifically, we were interested in their interest in using VR for two purposes: 1) Communication and Socialization 2) Staying cognitively active. Considering the potential mental health and cognitive implications of an extended enforced self-isolation during the pandemic, we expected to see higher levels of interest among the elderly to utilize technologies such as VR. We believe that restricted face to face interactions and the absence of entertaining activities would potentially contribute to more reliance on technology. We hypothesized that the majority of elderly people would welcome the use of VR technology for socialization during the COVID-19 pandemic. We also hypothesized that the majority of the elderly would welcome the use of VR technology for staying cognitively active during the COVID-19 pandemic.

Rationale:

This survey is the first study to investigate the attitudes of the elderly toward the use of technology including VR as a virtual method of communication, activity and entertainment. Results of the study will help us better understand the elderly's understanding and attitude toward the role of virtual reality, which will aid developers and/or public health agencies in designing programs that are more engaging for older users.

Hypotheses & Objectives:

The main objective of this study is to determine whether the COVID-19 pandemic has changed the attitudes of elderly people toward virtual reality (VR) technology. Given that VR technology could be used as a means of remaining socially connected and entertained during times of required self-isolation or social distancing, we hypothesize that elderly people will welcome the use of VR technology to socialize and stay cognitively active.

Specific Aim 1: To investigate the effect of the COVID-19 pandemic on elderly people's attitude toward VR technology as a socialization tool.

Hypothesis 1: We hypothesize that the majority of elderly people will welcome the use of VR technology for socialization during the COVID-19 pandemic.

Specific Aim 2: To investigate the effect of the COVID-19 pandemic on elderly people's attitude toward VR technology as a cognitive training tool.

Hypothesis 2: We hypothesize that the majority of elderly people will welcome the use of VR technology for staying cognitively active

2.2. Methods

2.2.1. Participants

Survey respondents included 103 elderly (66 female, 35 male, 2 preferred not to say) with a mean age of 72.25 (*SD* = 5.0). All respondents were residents of Manitoba who voluntarily decided to complete the survey questionnaire. Respondents' education background has been summarized in Table 2.

2.2.2. Survey

The survey included 11 questions which could be categorized into the following sections:

1) The first group of questions assessed individuals' daily use of technology (including mobile phone, personal computer, tablet computers) and the internet. In addition, respondents were asked to determine if they are using the internet more often after the emergence of COVID-19.
2) The second group of questions asked respondent to determine if COVID-19 pandemic has changed their interest in technology and their willingness to learn about new technologies.
3) The third category included questions about previous experience of individuals with video games and whether respondents find these games effective in improving memory, mood and hand-eye coordination.
4) In this category, participants indicated how frequently they use video communication apps. In addition, they would indicate if COVID-19 pandemic has changed the frequency of using this method of communication
5) In the beginning of this section, respondents read a short definition of Virtual Reality (VR) technology before responding to the questions associated with VR. Individuals were asked about any previous experience with VR and potential reasons for which they might be interested in VR. Additionally, they were asked to determine for what purposes they would have been interested in using VR during COVID-19 pandemic. Also, they were asked about the amount of money that they are willing to pay to purchase their own VR equipment.
6) The last section included demographic (gender, age and education)

All questions on the survey were closed-ended in one of the two following formats: 1) For Questions requiring the respondent to determine a specific category (e.g. potential reason for using VR), they were provided with multiple options to choose form 2) For questions requiring participants to indicate a frequency of using an equipment (e.g. mobile phone), they were provided with a 4 or 5 point scale to choose from. With the exception of questions 6b (potential positive effects of digital games) and 9d (potential uses of VR during the COVID-19 pandemic), participants were only allowed to choose one option.

The complete survey is available in Appendix B.

2.2.3. Procedure

Respondents were recruited from residents across Manitoba. Surveys were administered either online or by telephone. The online survey was set up using the SurveyMonkey website, and the link was advertised online so that individuals with internet access will be able to respond to the questions online. In order to include individuals who do not use internet regularly, we also administered phone surveys using the same questions. We contacted seniors' residences' management to inform them about the survey. Upon the approval of the residence's management, an anonymized list of resident's contact info was used. Potentially eligible residents were called to determine if they are interested in responding to a short survey about the use of VR during the COVID-19 pandemic. All individuals between the ages of 65 and 90 were included in the survey. There were no exclusion criteria other than age.

Chi-square goodness of fit and initial ordinal regression analysis was performed using SPSS 26.0 for Mac (SPSS, Chicago, IL), with p-values set to 0.05. Polychoric and polyserial correlations and simple regression analysis were performed using R 4.0.2 (R Core Team, 2020) and the following packages: "psych" (Version 2.0.7, Revelle, 2020), "foreign" (Version .8-80, R Core Team, 2020), "polycor" (Version .7-10, Fox 2019), "lavaan" (Version .6-6, Rosseel 2020) and "EFA.dimensions"(Version 0.1.6, O'Connor 2020). The full reproducible R codes are available in Appendix C.

2.3. Results

2.3.1. Virtual Reality for Communication

Of the 103 respondents of the study, 60 individuals had no interest at all to use VR for communication/interaction, 18 individuals were somewhat interested, 8 were moderately interested and 17 were very interested. A chi-square goodness of fit test was conducted to determine whether equal number of respondents were present in each of the interest level categories (not interested, somewhat interested, moderately interested, very interested). The minimum expected frequency was 25.8. The chi square goodness of fit test indicated that responses were not equally distributed among the four categories ($\chi^2(3) = 63.097$, $p = .000$), with more than half of the participants choosing "*not interested at all*" option.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of frequency of using other technologies (tablet, cell phone, personal computer and video communication apps), previous experience with digital games and prior knowledge of VR technology on the individuals' interest in using VR for communication. The final model only included frequency of using cell phone and video communication apps as these two had a statistically significant effect. In addition, gender and age were covariates in that model. Due to the high number of empty cells, the data was found to be unsuitable for logistic regression. Limited number of respondents created insufficient amount of data to correspond to various combination of variables in the logistic regression analysis, leading to extremely large beta coefficients for some variables. In other words, there were too many dependent variables levels (by observed combination of predictor variable values) that had zero frequencies. In order to preserve the ordinal nature of the data and run the regression, we computed polychoric and polyserial (for age) correlations to create a correlation matrix of all the variables in the model. Since using the raw data was found to be problematic (high number of empty cells), we used correlation values as inputs for our simple regression analysis. This procedure was carried out using structural equation modeling (SEM) in R software. Based on this model, interest levels significantly decrease as the frequency of mobile use increases (β=-.25, p=.001). Individuals were significantly more interested if they had used video communication apps more frequently (β=.71, p=.00). Man are more likely to show higher levels of interest in VR for communication purposes (β=-.30, p=.00). In addition, our model indicates that interest levels are not significantly predicted by age (β=.40, p=.59). Our proposed model could explain 49% of the variance in interest levels of the elderly. The proportion of variance explained by the model, standardized beta values, their significance values and standard errors have been summarized in table 9.

2.3.2. Virtual Reality for cognitive benefits

Of the 103 respondents of the study, 30 individuals had no interest at all to play VR games VR to stay cognitively active, 19 individuals were somewhat interested, 29 were moderately interested and 25 were very interested. A chi-square goodness of fit test was conducted to determine whether equal number of respondents were present in each of the interest level categories (not interested, somewhat interested, moderately interested, very interested). The minimum expected frequency was 25.8. The chi square goodness of fit test indicated that proportion of responses were not statistically significantly different among the four categories ($\chi^2(3) = 2.903$, $p = .419$).

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of frequency of using other technologies (tablet, cell phone, personal computer, video communication apps), previous experience with digital games and prior knowledge of VR technology on the individuals' interest in using VR to stay cognitively active. The final model only included frequency of using cell phone and tablet as these two had a significant effect. In addition, gender and age were covariates in the proposed model. Since there were high number of empty cells in the data, we concluded that the dataset is unsuitable for logistic regression. In order to preserve the ordinal nature of the data and run the regression, we computed polychoric and polyserial (for age) correlations and formed a matrix. We proceeded with a simple regression analysis utilizing structural equation modeling (SEM) to use the correlation matrix as the input. Based on this model, interest levels significantly increase as the frequency of using mobile (β=.18, p=.02) and tablet (β= .33, p=.00) increase. Respondents' interest levels significantly decline as their age increase (β=-.39, p=.00). Additionally, our model indicates that interest levels are not significantly predicted by gender (β=-.07, p=.36). The model could explain 35% of the variance in interest levels of the elderly. Proportion of variance explained by the model, standardized beta values, their significance values and standard errors have been summarized in table 10.

2.3.3. Virtual Reality for general entertainment, physical activity and online activity

Of the 102 respondents, 36 individuals had no interest at all to use VR for general entertainment, 29 individuals were somewhat interested, 21 were moderately interested and 16 were very interested. A chi-square goodness of fit test was conducted to determine whether equal number of respondents were present in each of the interest level categories (not interested, somewhat interested, moderately interested, very interested). The minimum expected frequency was 25.5. The chi square goodness of fit test indicated that responses were not equally distributed among the four categories ($\chi^2(3) = 9.137$, $p = .028$), with 35% of the participants choosing "*not at all interested*" option.

In response to the question regarding seniors' interest in using VR for staying physically active, 31 individuals had no interest at all to use VR for physical activity, 20 individuals were somewhat interested, 29 were moderately interested and 23 were very interested (N=103). The chi square goodness of fit test indicated that proportion of responses were not statistically significantly different among these four categories ($\chi^2(3) = 3.058$, $p = .383$).

Of the 103 respondents, 80 individuals had no interest at all to use VR for going online, 10 individuals were somewhat interested, 8 were moderately interested and 5 were very interested. A chi-square goodness of fit test was conducted to determine whether equal number of respondents were present in each of the interest level categories. The minimum expected frequency was 25.8. The chi square goodness of fit test indicated that responses were not equally distributed among the four categories ($\chi^2(3) = 152.883$, $p = .000$), with 77.7% of the respondents choosing "*not at all interested*" option.

2.3.4. Cost of VR equipment

Chi square goodness of fit test was utilized to assess whether equal number of respondents have chosen each price range (*less than $100, $100-$200, $200-$500, more than $500)*. The chi square goodness of fit test indicated that responses were not equally distributed among the four categories ($\chi^2(2) = 76.447$, $p = .000$), with about 72% of the respondents choosing "*less than $100*" as their desired cost for purchasing a VR equipment.

A summary of the responses to previous technology use, interest levels in using VR, desired cost for VR equipment and the effect of COVID-19 pandemic on respondents' interest in VR are available in tables 3-8. Reponses to all other questions are available in Appendix D.

2.4. Discussion

In the first section of our analysis, we assessed the elderly's interest in VR for communication. We had hypothesized that the majority of older individuals would welcome VR for communication purposes. Our survey indicated that more than half of our respondents were not interested at all. In addition, only 15.5% of respondents expressed any interest in using VR for communication during the COVID-19 pandemic (Table 6). We cannot support our hypothesis based on these finding. Due to the restricted visiting guidelines during COVID-19 pandemic, we expected to see a large proportion of our respondents to be more receptive to such alternatives. Considering recent research by Syed-Abdul and colleagues (2019) indicating seniors' interest in VR technologies, we speculate that seniors might be interested in using VR but they might have concerns that need to be addressed. Privacy has been one of the previously investigated concerns of seniors (Lorenzen-Hubber 2011) which might have been a critical factor in their decision about using VR for interacting with other individuals, including their friends and family. Our small sample size (*N*=103) do not allow us to generalize the survey results to the elderly population but we expect to see higher levels of interest among this portion of population if survey was done on a larger scale . We expect higher interest levels because of severe limitations in in-person communications for the elderly during the COVID-19 pandemic. We collected data during the first few months of the pandemic and it is possible that continued limitations of in-person communication would convince larger proportion of seniors to show interest in VR for communication purposes. It is also worth mentioning that 70% of respondents who had shown high interest levels (*very interested*) were 65 to 70 years old and approximately 42% of the respondents fall into this age range. Conducting a large-scale study with higher number of respondents in this age range would potentially indicate higher interest levels. In addition, a recent investigation of senior's attitude toward VR has reported an overall positive attitude of seniors toward VR (Syed-Abdul et al. 2019). Considering seniors' concern about privacy, informing them about measures in place to protect their privacy could potentially increase their interest levels.. Our proposed model has attempted to identify other variables which might be contributing to the interest level of older individuals for using VR as a communication tool.

The proposed model included four variables. While two of these variables are associated with previous experience with technology (mobile phone and communication applications), the other two are demographics (age and gender). This model was successful in accounting for approximately half of the variance in the interest level. Even though the model depicted the age variable as a non-significant predictor, we decided to include the variable as its inclusion resulted in a 20% increase in explained variance. It is likely that this variable might have had an indirect influence through interactions with variables not included in the model. According to the model, as frequency of using mobile phone increases, the interest level declines, but when the frequency of video communication increases, the interest level increases as well. We believe that this pattern is an important reminder to be more specific about "previous experience" with technology, as different experiences can lead to varying interest for newer generation of technologies. One potential explanation for different interest levels after increasing experience with these two technologies (mobile and video communication) could be the preferred type of communication. Interpretation of this finding is complicated since we are aware that respondents are using video communication apps to interact with others but we have not included a question asking them how they are using their mobile devices. If we had some level of certainty that seniors are only using phones for voice calls, we could speculate that there is a potential link between using video communication and VR use while such connection is absent between VR and audio calls with phone. Our model could not identify a statistically significant effect of age on individuals' interest levels. Current literature regarding the effect of age on seniors' interest is mixed as some studies have indicated decreased interest levels among the older adults, while others have reported a positive association between age and interest levels (Peek et al. 2014; Czaja et al. 2006, Lai et al. 2010). Regarding the interests of men and women, our data indicated higher levels of interest among men to use VR for communication. This finding is consistent with recent study by Halmdienst, Radhuber & Winter-Ebmer (2019), where they had found men to be more interested in using technological devices for communication and entertainment. It is possible that these two demographics contribute to the model by their interaction with other variables that are either not included in our model or the survey. For example, cultural background (Lai et al. 2010), desire to age in place and privacy concerns (Lorenzen-Hubber 2010) are not included in our survey but they might contribute to respondents' interest in VR.

We had also hypothesized that the majority of the elderly population would welcome VR technology to stay cognitively active during COVID-19 pandemic. We expected that limited access to variety of activities would affect individual's interest in using VR. Since the proportion of responses were not significantly different, we could not conclude that seniors have low or high interest in using VR to stay cognitively active. Combining our analysis of respondents' interest levels and our findings regarding preferred purposes for using VR, we might be able to have a better understanding of seniors' interest in using VR for this purpose. 56.3 % of respondents have reported that they would have been interested in using VR for cognitive benefits during the pandemic (Table 6). This portion of our sample (58 individuals) consisted of respondents who had reported that they are somewhat interested (9), moderately interested (24) and very interested (25). Addition of respondents who had mild interest (choosing *somewhat interested* and *moderately interested*) to the ones who were very interested has contributed to the overall 56.3%. In light of these findings, we might be able to conclude that a considerable proportion of elderly individuals in our sample have medium to high interest in using VR for cognitive benefits during the pandemic. Respondents who have reported lower interest levels might have considered new technologies to be ineffective or impractical (Dutra 2005; Lai et al. 2010). Additionally, separation of questions assessing their interest in entertaining activities and cognitive tasks might have misled some respondents as some respondents might have interpreted "tasks for staying cognitively active" as repetitive tasks without any entertaining value to them. Being more specific or including additional info could have provided a more precise picture of tasks for "staying cognitively active".

Our proposed model of interest in using VR for cognitive benefits included previous experience (with mobile phone and tablet), age and gender. These four variables successfully explained 35% of the variance in interest levels of the elderly individuals. Even though the model depicted the gender variable as a non-significant predictor, we decided to include the variable as its inclusion resulted in a 10% increase in explained variance. Similar to age in our previous model, it is likely that this variable might have had a confounding influence through interactions with variables not included in the model. The contribution of mobile phone and tablet use to our model is consistent with the models of acceptance (UTAT and TAM) and previous studies, which had highlighted the role of previous experience with technology in the seniors' perception and intent to use newer ones (Vankatesh, Morris & Davis 2003, Vankatesh & Bala 2008, Peek 2014). In order to interpret the role of using mobile phone and tablet through TAM and UTAT models, we could consider these two as modulating factors impacting behavioral intention, perceived ease of use and perceived usefulness of technology. In our study, respondents who used these devices more frequently were more likely to have higher interest in using VR to stay cognitively active; However, previous experience with personal computers was not a significant predictor and not included in our model. Since mobile phones and tablets both are considered portable devices, we speculate that respondents who are interested in portable technologies are more likely to be interested in using VR to derive cognitive benefits. Our findings regarding age is consistent with large dataset such as National Health and Ageing Trends Study (Gell et al. 2015), where they observed decreased interest in older individuals. Our model did not find gender to be a significant predictor, which contradicts recent findings by Halmdienst, Radhuber & Winter-Ebmer (2019) in which they had indicated that women show more interest in health benefits of technology. Our data indicated that women are just as likely as man to be interested in using VR for cognitive benefit. We believe there are two explanation for this observation: 1) Respondent may not have considered cognitive capacities as a vital portion of their overall health and consequently expressing lower interest to use VR for cognitive benefits 2) Due to unfamiliarity of the aging population with VR, they might have perceived VR as less/not beneficial to their health. It is possible that these respondents might still be interested in using other types of technology for health benefits.

Our analysis of responses to VR use for general entertainment indicated that a significant number of respondents were not interested at all; However, 38.8% of respondents reported that would be interested in using VR for general entertainment during the pandemic. This group of our sample (40 individuals) consisted of 9 respondents who had chosen *somewhat interested*, 15 respondents who had chosen *moderately interested* and 16 respondents who had chosen *very interested* option. We believe that term "general entertainment" may not have conveyed the entertaining capacity of VR devices as a large proportion (98.1%) of our sample have never used VR devices before.

Our data could not support a significant difference among response options of interest levels for VR-based physical activity. We believe that respondents' health status and age might play a crucial role in their interest for virtual physical activities. We do not have any information about health status or physical limitation of individuals in our sample. Considering the mean age of the sample (72.2 years old), it is possible that some of them have physical limitations which would limit their capacity and interest in various types of physical activity; However, in response to another question in the survey, 57.3% of respondents expressed interest in physical activities using VR during the pandemic (Table 6). Indoor confinement and limited choice of activities (caused by COVID-19) might have convinced some respondents to consider VR as a viable option for physical activity during the pandemic. This might have led to a higher percentage of respondents (57.3%) expressing their interest in using VR for physical activity during the pandemic.

Our analysis of individuals' interest in using VR for searching for information on the internet indicated that a significant proportion of the respondents are not interested at all. This is in line with our findings regarding individuals' comfort level with using the internet where approximately 66% of the respondents were *neither comfortable nor uncomfortable* or *somewhat uncomfortable*. Since a large portion of our sample are not using the internet on other platforms, (tablet, personal computer, etc.), it is not surprising they would have lower interest levels in using the internet on a less familiar platform such as VR. We should also consider responses to question 13 where we observed that 61.2% of our respondents have reported that they are using the internet more often since the beginning of the COVID-19 pandemic. It appears that seniors are going online more often but they still do not consider VR as the optimal platform for going online. It is possible that respondent do not have a clear understanding of how they could search for information online in a VR environment.

Our result regarding a desired price range for VR equipment is in line with previous research (Vaportzis, Giatsi Clausen & Gow 2017) highlighting seniors concerns about the cost of new technologies. The majority of our respondents (~72%) prefer to purchase a VR equipment for less than $100, while current available VR devices could cost $300 or more (Greenwald, 2020). This discrepancy could be an important factor in seniors' decision regarding VR and its various uses such as communication, entertainment and physical activity.

Based on the proportion of responses to the effects of COVID-19 pandemic (Table 8), 56.3% of respondents reported an increased interest in VR as a result of the pandemic, indicating that a large proportion of elderly individuals have become interested in VR. Considering that 51.5% of respondents have reported an increased interest in using all types of technology as a result of the pandemic, we could conclude that COVID-19 pandemic has boosted senior's interest in using different types of technology, including VR. According to our data, staying cognitively and physically active were the top desired reasons for which seniors wanted to have access to a VR device during the COVID-19 pandemic. We believe that providing more information about the versatility of VR would have boosted individuals' interest in VR as only 1.9% of respondents of the study had previous experience in using VR and 45.6% had heard about it before. This limited information could be attributed to respondents' use of the internet. Almost half of the respondents (49.5%) rarely use the internet and only 26.2% of the respondents feel comfortable using the internet (5.8% *very comfortable* and 20.4% *somewhat comfortable*). In other words, limited use of the internet could have contributed to limited information about VR.

Our study included a small sample of the elderly population. Collecting a higher number of responses from the population could potentially identify more contributing variables and increase the power of our analyses. In addition to the size of our sample, it is important to note that we have collected limited information about respondents (age, gender and education). Inclusion of more questions about personal characteristics might be beneficial in aiding us to distinguish individual's attitudes based in their characteristics. For example, short personality and lifestyle questionnaires could provide us with valuable information about the association of these factors with individual's attitude toward technology. Another limitation in our study is our reliance on self-reported data. Surveys were filled anonymously and we cannot independently verify the data. Furthermore, our population are above the age of 65 and they are more likely to have higher number of inaccurate responses in a self-report survey. This issue has been highlighted in previous studies (Knauper et al. 2016; Carstensen & Hartel 2006), where they have stated that observed age differences in self-report surveys might be a reflection of a true difference, different response processes of the elderly or a mixture of these two conditions. In addition, having memory deficits might also boost the possibility of inaccurate responses as some studies (Krester et al. 2012) have shown that memory impaired individuals are more likely to report inaccurate responses if the survey items are bidirectional. This might have affected our results as our survey questions regarding “interest in using VR” were bidirectional. Finally, some of the terms in the survey could be further explained to clarify the meaning. For instance, not all respondents may have the same interpretation of “games for staying cognitively active” based on their previous experience. To address the limitation in our study, future studies could benefit from larger sample sizes, more detailed questions regarding personal characteristics of respondents and more detailed descriptions of technologies included in the survey.

To summarize, our research has indicated that a large proportion of elderly individuals have become interested in VR technology as a result of the COVID-19 pandemic . While our findings show higher interest levels in using VR for staying cognitively and physically active during the pandemic, our data demonstrated lower interest levels in using VR for communicating and searching for information on the internet. Even though respondents expressed low interest levels toward VR-based entertainment, approximately 39% of them considered VR entertainment as a desirable option during the COVID-19 pandemic. We have developed two new models reflecting the role of experience with previous technology, gender and age on senior’s attitudes toward: 1. using VR for communication and 2. using VR to stay cognitively active. These findings add to the current literature of the elderly individuals' attitude toward technology. Our model of VR use for communication was found to account for approximately 50% of variance in interest levels and our model of VR use for cognitive benefits could account for 35% of variance. These models could potentially aid us to identify proportions of this population who are more likely to welcome VR for communicating and staying cognitively active.

Table 2

Respondents' level of education

Highest completed education level	*N*	%
Some high school, no diploma	7	6.8
High school graduate, diploma, or equivalent	40	38.8
Some college credit, no degree	15	14.6
Trade/Technical/Vocational training	22	21.4
Associate Degree	3	2.9
Bachelor's degree	16	15.5
Total	103	100%

Table 3

Frequency of using technology

	Never		Once or Twice		Multiple Times		Constantly	
	N	%	*N*	%	*N*	%	*N*	%
Mobile Phone	8	7.8	35	34	32	31.1	28	27.2
Personal Computer	45	43.7	31	30.1	24	23.3	3	2.9
Tablet Computer	69	67	15	14.6	16	15.5	1	1

Table 4

Frequency of using video communication apps

How often do you use video communication apps (such as FaceTime, Skype, or Zoom) to stay in touch with your family and friends?	*N*	%
Everyday	1	1
Multiple times a week	18	17.5
Once a week	16	15.5
Once or twice a month	23	22.3
A few times a year	7	6.8
Never/very rarely	38	36.9

Table 5

Interest in using VR for different purpose

	Not at all interested		Somewhat interested		Moderately interested		Very interested	
	N	%	*N*	%	*N*	%	*N*	%
Communicating/interacting	60	58.3	18	17.5	8	7.8	17	16.5
Searching for information	80	77.7	10	9.7	8	7.8	5	4.9
Playing games to stay cognitively active	30	29.1	19	18.4	29	28.2	25	24.3
Playing games to stay physically active	31	30.1	20	19.4	29	28.2	23	22.3
General Entertainment	36	35	29	28.2	21	20.4	16	15.5

Note. There is one missing response for the "general entertainment" section

Table 6

Desired purposes for using VR during COVID-19 pandemic

For which of the following purposes do you think you would have used VR technology If you had access to it during the COVID-19 pandemic?	*N*	%
Communicating or virtually interacting with other people	16	15.5
Searching for information on the internet	5	4.9
Playing games to stay cognitively active	58	56.3
Playing games to stay physically active	59	57.3
General entertainment (e.g. watching shows, going on virtual tours, etc.)	40	38.8

Table 7

Desired cost for a VR equipment

How much money would you be willing to spend to purchase your own virtual reality equipment?	*N*	%
Less than $100	74	71.8
$100-$200	26	25.2
$200-$500	3	2.9
More than $500	0	0

Table 8

The effect of self-isolation on individuals' interest in using VR

Has the enforced self isolation of the COVID-19 pandemic increased your interest in using VR technology?	*N*	%
Yes	58	56.3
No	44	42.7
No response	1	1

Table 9

Components of the proposed model for using VR to communicate

	B	*SE B*	*ß*	*p*	R^2	Adjusted R^2
Model					.51	.49
Intercept	2.96	1.38		.033		
Frequency of using mobile	-.30	.09	-.25	.001*		
Frequency of using video communication	.52	.06	.71	.000*		
Gender	-.59	.14	-.30	.000*		
Age	-.01	.02	-.04	.596		

*$p < .05$

Table 10

Components of the proposed model for using VR to stay cognitively active

	B	*SE B*	*ß*	*p*	R^2	Adjusted R^2
Model					.37	.35
Intercept	7.85	1.51		.000		
Frequency of using mobile	.22	.10	.18	.021*		
Frequency of using tablets	.48	.12	.33	.000*		
Gender	-.15	.17	-.07	.362		
Age	-.09	-.02	-.39	.000*		

*$p < .05$

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Appendix A

Consent Form

RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM

Title of Study: ***"Assessing the impact of an immersive VR gaming experience on navigation ability and spatial cognition in an elderly population"***

Principal Investigator:	**Mandana Modirrousta**	Winnipeg, MB	204-237-2606
Co-Investigator:	**Bruce Bolster**	Winnipeg, MB	204-786-9338
Research Assistant:	**Ali Tavakoli**	Winnipeg, MB	
Research Assistant:	**Benjamin Meek**	Winnipeg, MB	204-237-2677

This project is being funded by the Mitacs Accelerate program in collaboration with Project Whitecard Inc.

You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your friends, family or (if applicable) your doctor before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

Purpose of Study

This research study is being conducted to examine the effect of playing a virtual reality (VR) computer game on older peoples' spatial and navigation abilities. Specifically, we want to find out whether peoples' ability to navigate a real-world environment and remember the location of objects is improved by repeated exposure to a VR computer game. In order to assess the specific effect of the VR training, people in this study will be tested after playing VR games as well as after playing jigsaw-puzzle games, and performance changes will be compared between the two types of games.

What is virtual reality? VR is a computer-generated environment that can be moved through and interacted with. People can experience the simulated environment by using a virtual reality headset, which is a device that looks like ski goggles and contains small computer screens and speakers. The user can interact with the virtual environment by pressing buttons on hand-held video-game controllers.

A total of 50 healthy individuals between the ages of 60 and 90 will participate in this study.

Study Procedures

If you take part in this study, you will complete a total of 14 sessions. Four of the sessions will last approximately one hour, while the other 10 sessions will take 20-30 minutes each.

Session 1: You will be asked some general questions regarding your health (including past medical history and current medications), and you will complete questionnaires assessing your mood. You will then complete a number of questionnaires, tasks, and computer tests that will assess aspects of your cognition, including attention, pattern and object recognition, visual and verbal memory, reaction time, and concentration.

Session 2: You will complete three tasks using a virtual reality program that will test your navigation and spatial memory abilities in a variety of environments. You will also complete a real-world task that requires you to remember the names and locations of objects placed on various tables.

Sessions 3-12 will take place on successive weekdays spread across two weeks. In each daily session you will spend 20 minutes playing either a VR game or assembling jigsaw puzzles, depending on the group to which you are first assigned. Assignment to a group will be done randomly (like flipping a coin) using a computer. If you are in the VR group: you will play a game called DoVille VR. In this game, you will follow a narrative story by searching for clues and visiting various landmarks in a virtual city. In order to finish the game, you will need to navigate around the city and use the available clues to solve a mystery. If you are in the non-VR group, you will be asked to assemble a jigsaw puzzle during your daily 20 minute gaming period.

Sessions 13&14: During the final two sessions, you will repeat the same cognitive testing and real world tasks that you performed in the first two sessions.

You can stop participating in this study at any time. Results of the study, once completed, will be provided to you upon your request.

Risks and Discomforts

Some people experience headaches, nausea or dizziness while using a VR headset. You are free to stop the game at any point if you feel uncomfortable using the VR system.

Benefits

There may or may not be direct benefit to you from participating in this study. Participating in a daily activity as part of this study (either VR or non-VR gaming) may have beneficial cognitive effects, especially with regards to your spatial navigation and scene memory.

Costs

There will be no financial cost to you for participating in this study.

Payment for Participation

You will not receive payment or financial reimbursement for taking part in this study.

Confidentiality

Information gathered in this research study may be published or presented in public forums; however your name and other identifying information will not be used or revealed. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed. Your personal information may be disclosed if required by law. Authorized persons of

Government, ethical and regulatory bodies, including the Health Research Ethics Board, and the University of Manitoba may look at the study records without violating confidentiality to check that the study has been properly conducted. This can only be done with your permission, and it is therefore understood that by signing the Consent Form you are thereby granting this permission.

All study related documents will bear only your assigned study number and/or initials. Identifiers and any paper records that contain your identity will be treated as confidential in accordance with the Personal Health Information Act of Manitoba. All records will be kept in a locked secure area and only study staff will have access to these records. A copy of your study data will be shared with the industry partner of this study – Project Whitecard Inc. If any of your research records need to be copied, your name and all identifying information will be removed. No information revealing any personal information such as your name, address or telephone number will leave Dr. Modirrousta's laboratory space at St. Boniface Hospital. This procedure ensures the de-identification of all paper and electronic documents stored as part of this study.

All research data entered into the computer for storage and analysis will be de-identified. This means that data will be labelled with your study number only, rather than any identifying information.

The data collected from you during this study may be shared in an anonymized or de-identified form with academic journals for publication purposes or other researchers according to international guidelines. The data may also be stored by the academic journal under an open access policy in which case it may be used by other researchers for further data analysis and research purposes. Before publishing/sharing any data, it will be reviewed with the Research Ethics Board or oversight committee to ensure full compliance with privacy legislation.

Voluntary Participation/Withdrawal from the Study

Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time. Your decision not to participate or to withdraw from the study will not affect your care at this centre. If the study staff feels that it is in your best interest to withdraw you from the study, they will remove you without your consent.

We will tell you about any new information that may affect your health, welfare, or willingness to stay in this study.

Medical Care for Injury Related to the Study

If you should become physically injured as a result of any research activity, the study doctor will provide any necessary treatment, at no charge, to help you promptly recover from the injury.

Questions

You are free to ask any questions that you may have about this study and your rights as a research participant. If any questions come up during or after the study or if you have a research-related injury, contact the study principal investigator: Dr. Mandana Modirrousta at (204) 237-2606.

For questions about your rights as a research participant, you may contact The University of Manitoba, Bannatyne Campus Research Ethics Board Office at (204) 789-3389.

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

Statement of Consent

I have read this consent form. I have had the opportunity to discuss this research study with Dr. Mandana Modirrousta, Dr. Bruce Bolster, and/or their study staff. I have had my questions answered by them in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor or family member) I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that information regarding my personal identity will be kept confidential, but that confidentiality is not guaranteed. I authorize the inspection of any of my records that relate to this study by the University of Manitoba Research Ethics Board and the University of Manitoba for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

I agree to be contacted for future follow-up in relation to this study, Yes __ No __.

______________________________ ____________________
Signature of Participant Date

____
Printed Name of Participant

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has knowingly given their consent

______________________________ ____________________
Signature of Study Staff Date

____
Printed Name of Study Staff

Role in the study: ____________________________

Appendix B
Survey Questions

1. Please indicate how often you use each of the following technologies every day:

Device	*Never*	*Once or Twice*	*Multiple Times*	*Constantly*
Mobile Phone				
Personal Computer (i.e. desktop or laptop)				
Tablet Computer (e.g. iPad)				

2. How often do you go online and use the internet?
   a) Several times a day
   b) Once a day
   c) Once a week
   d) Rarely

3. How comfortable are you using internet?
   a) Very comfortable
   b) Somewhat comfortable
   c) Neither comfortable nor uncomfortable
   d) Somewhat uncomfortable
   e) Very uncomfortable

4. Have you been using the internet more often since the start of the COVID-19 Pandemic?
   a) Yes
   b) No

5. How has the COVID-19 Pandemic changed your interest in using technology?
   a) No change
   b) My interest in technology has <u>increased</u>
   c) My interest in technology has <u>decreased</u>

6. How has the COVID-19 Pandemic changed your willingness to learn to use new technology?
   a) No change
   b) My interest in technology has <u>increased</u>
   c) My interest in technology has <u>decreased</u>

6a. Have you ever played digital games on a computer, cell phone or tablet?
a) No
b) Yes

If YES:

6b.Do you feel that playing digital games has positively affected any of the following in your daily life (Check all that apply):

a) Hand and eye coordination
b) Memory
c) Mood

7. How often do you use video communication apps (such as FaceTime, Skype, or Zoom) to stay in touch with your family and friends?
   a) Never/very rarely
   b) A few times a year
   c) Once or twice a month
   d) Once a week
   e) Multiple times a week
   f) Every day

8. Compared to before the Pandemic started, how frequently do you use video communication technology?
   a) Much more than before
   b) Somewhat more than before
   c) About the same as before
   d) Somewhat less than before
   e) Much less than before

"**Virtual reality (VR)** is a technology by which computer-generated stimuli shown through a video headset create the immersive illusion of being in another environment"

9a) Have you ever heard of Virtual Reality Technology before?
   a) Yes
   b) No
9b) Have you ever used Virtual Reality Technology before?
   a) Yes
   b) No

9c) How interested would you be to use VR technology for the following purposes?

	Not at all interested	Somewhat interested	Moderately interested	Very interested
Communicating or virtually interacting with other people				
Searching for information on the internet				
Playing games to stay cognitively active				
Playing games to stay physically active				

General entertainment (e.g. watching shows, going on virtual tours, etc.)				

9d) For which of the following purposes do you think you would have used VR technology if you had access to it during the COVID-19 Pandemic? (Check all that apply):

a) Communicating or virtually interacting with other people
b) Searching for information on the internet
c) Playing games to stay cognitively active
d) Playing games to stay physically active
e) General entertainment (e.g. watching shows, going on virtual tours, etc.)

9e) Has the enforced self-isolation of the COVID-19 Pandemic increased your interest in using VR technology?

a) Yes
b) No

10. How much money would you be willing to spend to purchase your own virtual reality equipment?

a) Less than $100
b) $100-$200
c) $200-$500
d) More than $500

11a. What is your gender?

a) Male
b) Female
c) Other
d) Prefer not to say

11b. What is your age? _ _

11c. What is the highest degree or level of school you have completed?

a) No schooling completed
b) Nursery school to 8th grade
c) Some high school, no diploma
d) High school graduate, diploma or the equivalent (for example: GED)
e) Some college credit, no degree
f) Trade/technical/vocational training
g) Associate degree
h) Bachelor's degree
i) Master's degree
j) Professional degree
k) Doctorate degree

Appendix C
R Codes

```
install.packages("psych")
library(psych)
library(foreign)
ali <- read.spss("Attitudes of the elderly towards Virtual Reality Copy gaming and socializat-2.sav", use.value.labels=FALSE,
    to.data.frame=TRUE,  max.value.labels=Inf,  trim.factor.names=FALSE);
names(ali) # displays the variable names in data
ali2 <- ali[,c('q009c_0001', 'q0001_0001', 'q0007', 'q0011a', 'q0011b')]
dim(ali2)
ali2 <- na.omit(ali2) # dropping cases with missing values
dim(ali2)
install.packages("EFA.dimensions")
library(EFA.dimensions)
polycorrels <- POLYCHORIC_R(ali2, method = 'Revelle')
library(polycor)

ali3          <- ali2
ali3$q009c_0001 <- factor(ali2$q009c_0001,levels=1:4,ordered=T)
ali3$q0001_0001 <- factor(ali2$q0001_0001,levels=1:4,ordered=T)
ali3$q0007      <- factor(ali2$q0007,     levels=1:6,ordered=T)
ali3$q0011a     <- factor(ali2$q0011a,    levels=1:2,ordered=T)
ali3$q0011b      <- ali2$q0011b
dim(ali3)
hetcorrels <- hetcor(ali3)
hetcorrels

library(lavaan)
N <- nrow(ali3)
means <- sapply(ali2, mean)  # use ali2 because cannot compute means of factor variables
SDs <- sapply(ali2,sd)  # use ali2 because cannot compute SDs of factor variables
cor2cov <- function(V, sd) { V * tcrossprod(sd) }
covmat <- cor2cov(hetcorrels$correlations, SDs)
fit <- lavaan::sem("q009c_0001 ~ q0001_0001 + q0007 + q0011a + q0011b",
                 sample.cov = covmat,
                 sample.mean = means,
                 sample.nobs = N)
summary(fit)
coef(fit) # unstandardised coefficients
standardizedSolution(fit) # Standardised coefficients
inspect(fit, 'r2') # r-squared
adjr2 <- function(rsquared, n, p) 1 - (1-rsquared)  * ((n-1)/(n-p-1))

adjr2(inspect(fit, 'r2'), n = inspect(fit, "nobs"), p = 4)
```

Appendix D
Summary of Responses

Table 11

Internet usage

How often do you go online and use the internet?	*N*	%
Several times a day	9	8.7
Once a day	41	39.8
Once a week	2	1.9
Rarely	51	49.5

Table 12

Level of comfort using the internet

How comfortable are you using the internet?	*N*	%
Very comfortable	6	5.8
Somewhat comfortable	21	20.4
Neither comfortable nor uncomfortable	36	35
Somewhat uncomfortable	32	31.1
Very uncomfortable	7	6.8
No response	1	1

Table 13

Changes in the internet use since the beginning of COVID-19 pandemic

Have you been using the internet more often since the start of the COVID-19 pandemic?	*N*	%
Yes	63	61.2
No	39	37.9
No response	1	1

Table 14

The effect of COVID-19 on the use of technology

How has the COVID-19 pandemic changed your interest in using technology?	*N*	%
No change	50	48.5
My interest in technology has increased	53	51.5
My interest in technology has decreased	0	0
No response	0	0

Table 15

The effect of COVID-19 on the willingness to learn about technologies

How has the COVID-19 pandemic changed your willingness to learn to use new technology?	*N*	%
No change	59	57.3
My interest in technology has increased	42	40.8
My interest in technology has decreased	0	0
No response	2	1.9

Table 16

Previous experience with digital games

Have you ever played digital games on a computer, cellphone or tablet	*N*	%
Yes	56	54.4
No	47	45.6
No response	0	0

Table 17

Possible positive effects of video games

Do you feel that playing digital games has positively affected any of the following in your daily life? (Check all that apply)	*N*	%
Hand & eye coordination	9	8.7
Memory	27	26.2
Mood	36	35
No response	31	30.1

Table 18

The effect of the COVID-19 pandemic on using video communication apps

Compared to before the Pandemic started, how frequently do you use video communication technology?	*N*	%
Somewhat less than before	27	26.2
About the same as before	75	72.8
No response	1	1

Table 19

Previous experience with Virtual Reality (VR)

Survey Question	Yes		No	
	N	%	*N*	%
Have you ever heard of Virtual Reality Technology before?	47	45.6	56	54.4
Have you ever used Virtual Reality Technology before?	2	1.9	101	98.1

Table 20

The effect of self-isolation on individuals' interest in using VR

Has the enforced self isolation of the COVID-19 pandemic increased your interest in using VR technology?	*N*	%
Yes	58	56.3
No	44	42.7
No response	1	1