Investigation of Virtual Worlds as a Platform to Support Healthy aging for older people

A Thesis Submitted to the University of Kent at Canterbury
for the Degree of PhD
in Electronics

By
Panote Siriaraya
June 2013

Abstract

Due to the aging of the population in recent years, it is becoming essential to find innovative activities to help the increasing older population maintain an active lifestyle and delay the need for institutionalized care. Virtual worlds, which have many potential values such as in providing social engagement, could be used to support older people in this aspect. Despite this, most research and design of virtual worlds today are based on young users and do not coincide well with the interests and requirements of older people. It is therefore necessary to investigate how virtual worlds can be designed to not only meet the needs of older users but also to provide opportunities for social engagement and support healthy aging.

In the first stage of the research, a series of studies were carried out with older virtual world users to investigate their characteristics, interests and activities. This includes a qualitative interview study and an empirical study. Older users were able to develop interpersonal relationships in virtual worlds and were interested in activities which made useful contribution to society or those which allowed them to socialize with people who share similar interests. Next, two experiment studies were carried out, the first to investigate age related differences in virtual social interaction and the second to determine how different factors influence the social interaction experience. Factors such as navigation were found to influence social interaction and the study revealed limitations relating to the usefulness of the avatar.

The findings from this thesis helps extend our theoretical understanding of the interactions and activities of older people in virtual worlds and how previously identified concepts regarding virtual social interaction relate to older users. In addition, the findings were also applied into guidelines to aid developers in creating better virtual worlds to facilitate social interaction and healthy aging.

Keywords: Virtual worlds, older people, social interaction, healthy aging

This thesis is dedicated to my parents and my sister whom have been a great source of encouragement and support

Acknowledgement

First off, I would like to thank my supervisor, Dr. Chee Siang Ang for his wise guidance and kind support. Without him this project would have not progressed as smoothly and promptly as it has. I would also like to thank my co-supervisor, Prof. Sarah Spurgeon for all the wonderful feedback she has given towards this project. Ania Bobrowicz has also been extremely helpful in giving me advice in regards to the project.

I would also like to extend a special thanks to Jenny Oliver, Jenny Harris and Joshua Tricky who helped facilitate the recruitment of participants for my study and also to the members of the Woman's institute, the U3A in Canterbury and to all the other participants who (despite some of their misgivings in engaging with such a novel technology as virtual worlds) took part in my studies which made this project possible.

I am also grateful to the fellow members of my research group who provided me with an extremely warm and pleasant environment to work in. Special thanks to Mike Green, Wala Alharthi, Sumita Chauhan and Sam Frewer for helping teach me about 3D modelling and for donating some of their 3D models for me to use in my project. I also have the IT support team at our department, especially Paul Sinnock to thank for providing the server space necessary to host my virtual world study.

Finally, I would like to thank my family and my sister for their kind support and encouragement and also the University of Kent for providing me with a scholarship funding that enabled me to carry out this research.

Table of Contents

List of Figures

List of Tables

List of Acronyms

CMC: Computer mediated communication
EU: European Union
HCI: Human computer Interaction
ICT: Information computer technology
RITE: Rapid iterative testing and evaluation
MMOG: Massively multiplayer online game
MMOVE: Massively multiplayer online virtual environments
MMORPG: Massively multiplayer online role-playing games
MUD: Multi-user dungeon
NY: New York
SD: Standard Deviation
SDK: Software development kit
SL: Second Life
TAM: Technology Acceptance Model
UN: United Nations
UNECE: United Nations Economic Commission for Europe
VOIP: Voice Over Information Protocol
VIF: Variance inflation factor
WHO: World Health Organization
WWW: World wide web

Chapter 1: Introduction

1.1 Background

The society we live in today is aging rapidly. A UN report published in 2007 predicted that the global proportion of older people could reach 22% by the end of 2050 (UN , 2007). Europe faces similar problems, with almost 30% of the population predicted to be older than 65 by 2050 (European Commission, 2007). These demographic changes are thought to have major consequences and implementations in future society, especially on social care systems and health care services (UN , 2007). Based on these predictions, it is clear that we need to find innovative ways to help the increasing older population maintain an active lifestyle and delay the need for institutionalized care.

In recent years, computer technology has shown promise in this context. Through the internet, older people who are restricted by mobility are able to access information on essential topics such as healthcare, participate in lifelong learning and improve the performance of everyday tasks (Czaja & Lee, 2007). Online communities in the form of web based forums have also been argued to help provide older people with emotional support and users in such platforms were able to develop interpersonal and supportive relationships (Wright, 2000), (Pfeil, Zaphiris, & Wilson, 2009). Even computer games, traditionally viewed as an avenue of entertainment for the younger generation, have been suggested to have numerous therapeutic benefits such as preventing declines in intellectual and cognitive abilities (Griffiths, 2005).

Virtual worlds refer to computer-simulated environments that users can inhabit and interact with through the use of their avatars. Such systems combine the information providing element of the internet, the social element of online communities as well as the interactivity of computer games. Individually, each of these technologies has been used successfully to support older people. However, virtual worlds offer a combination of all these elements and can provide opportunities for users to engage in activities of similar benefits in a manner which can be experienced as more immersive and realistic. For instance, virtual worlds can present health information to users more intuitively through the use of a 3D environment (Boulos, Ramloll, Jones, & Toth-Cohen, 2008) . In addition, social interaction in virtual environments can be more interactive. While other online communities restrict communication only to text or voice, users in virtual worlds can use their avatars to interact with their partners in meaningful ways through the use of gestures or shared social activities.

Therefore, if virtual worlds could be appropriately designed, such platforms could potentially be used to support older people in unique and innovative ways. Indeed, some of the contexts in which virtual worlds are currently being used (such as to provide health

information, education or social engagement) could be of great benefit to older people (more explanation is given in section 2.5.4). One can imagine how beneficial it would be for an older person who is limited in mobility (caused either by diseases or naturally due to the aging process) to be able to participate in social activities or to be able to take part in educational classes in a virtual classroom from the comfort of their own home.

1.2 Problem statements

Despite the potential benefits of such systems, there has not been much work done to study the use, interaction and behaviour of older people in 3D virtual world systems. Current studies of 3D virtual worlds and older users have been focusing mostly on using virtual worlds more as a component in an integrated system. For instance, one study used a virtual world to visualize data from wireless sensors to provide information for caretakers (Boers, Chodos, Huang, Gburzynski, Nikolaidis, & Stroulia, 2009). Another study used a virtual world as part of a rehabilitation system which aims to encourage older people to exercise (Heller, Wheat, Wright, & Mawson, 2008). Other studies carried out with older users have looked into technologies with similar features as virtual worlds such as virtual reality devices (see (Flynn, Schaik, Blackman, Femcott, Hobbs, & Calderon, 2003)).

More recently, there have been studies investigating the interaction of older people with certain aspects of virtual worlds. For instance, one study investigated older user's perception towards avatars (Cheong, Jung, & Theng, 2011). Another study focused on improving the ability of older people to navigate in 3D virtual environments (Sjolinder, Hook, Nilsson, & Andersson, 2005). However, there have been few studies investigating older people's interactions in a fully functional virtual world. We know very little about how older people interact with each other in the virtual world and what their interests are in using such technology. Most studies in this context focus on general users, typically teenagers and younger adults (see section 2.6). The findings from these studies might not coincide well with older people, who have characteristics, needs and interests which differ from younger users due to the process of aging. Such knowledge would be invaluable for designers in creating virtual environments for older people, especially those which can effectively support healthy aging. This PhD project aims to provide such knowledge via in depth studies

1.3 Aim and research questions

The aim of this thesis is to investigate the use of virtual worlds by older people and their interactions with this platform. Based on the findings, suggestions are provided to aid developers in designing better virtual worlds to support healthy aging. This thesis will provide answers to the following research questions:

1. *What are the characteristics of older virtual world users and what activities do they carry out in virtual worlds?*

Understanding the characteristics, interests and activities of older virtual world users would be the first step in designing appropriate virtual worlds for older people. Activities designed to support healthy aging must be in line with the interests and preference of older people in order to be truly effective. This question is addressed mainly in chapter 3 where older virtual world users were interviewed about their experience of using virtual worlds and in chapter 4 where data from the online profiles of older virtual world users were collected and analyzed in comparison with younger users.

Originally, this thesis planned to investigate the general interactions and behaviours of older people in 3D virtual worlds. Many of the concepts explaining user interaction in virtual worlds were created based on studies carried out with younger users and little is known about the implications of such findings with older people. However in addressing the first research question, social interaction was found to be a key component in how older people engaged with virtual worlds and in the activities which had potential to support healthy aging. Therefore, the research questions were revised to focus more specifically on this aspect.

2. *What are the age differences in user engagement (i.e. quality of social interaction, physical presence etc) and the display of non verbal behaviour in social interaction in the virtual world between older users and the typical young user?*

   A virtual island experiment study carried out in chapter 6 identifies the age related differences between older and younger users in how they interact with virtual worlds, focusing on social interaction. Age differences in non verbal behaviours were also analyzed.

3. *What factors affect social interaction experience among older people in 3D virtual worlds and how could social interaction in virtual worlds be improved for older people?*

   The third research question aims to investigate what and how various aspects of the virtual world (the avatar etc) or of older users themselves (previous computer experience etc) influence social interaction experience in virtual worlds. Understanding these factors would be the first step in determining how virtual worlds could be improved to further facilitate social interaction for older people. This question is addressed mainly from the virtual store experiment study. Factors which affect social interaction experience have been analyzed through questionnaires and semi-structured interviews. The results from these studies are presented in chapters 7.

4. *How can effective activities that support healthy aging for older people be designed in virtual worlds?*

   The final research question is answered by synthesising the knowledge from the studies reported in chapters 3, 4, 6, 7. Based on the findings from these studies, suggestions have been made on how activities which would be beneficial in

supporting healthy aging can be designed. The results could be found in chapter 8.

1.4 Contribution

The key contribution of this study is to shed light on how older people interact with 3D virtual environments, a topic which has so far received little attention in HCI research. This thesis offers considerable theoretical and practical contributions to the topic. The overall key contributions from this thesis could be summarized as follows:

1. An understanding of the key characteristics of older virtual world users and their interests, interaction patterns and activities inside virtual worlds (Chapters 3 and 4)

2. An understanding of the various factors which affect social interaction experience for older people in 3D virtual worlds (Chapter 7).

3. Extending the understanding of various previously established concepts and findings related to user interaction in virtual worlds for older people. Studies investigating concepts such as social presence or non verbal social behaviour usually focus on younger users. Age difference analysis carried out in chapters 4 and 6 have identified some of the differences in these concepts between older and younger users.

4. Practical implications such as suggestions to aid developers in creating virtual worlds which better facilitate social interaction and suggestions in designing better activities to support healthy aging for older people (Chapter 8).

5. Methodological contributions such as the design of a virtual world system which can be used to carry out experiment studies with older people (Chapter 5).

Finally, the findings from these studies were publicized in a number of peer reviewed journals, with the aim of extending the existing knowledge in the research community by contributing to the overall understanding of older user's engagement with virtual worlds. Table 1 summarizes the publications which have arisen directly from this thesis project.

Chapter	Journal/Conference	Title	Citation
3	Behaviour & Information Technology, Journal (in press)	Exploring the potential of virtual worlds in engaging older people and supporting healthy aging.	(Siriaraya, Ang, & Bobrowicz, in press)
4	Computers in Human Behaviour, Journal (2012)	Characteristics and usage patterns of older people in a 3D online multi-user virtual environment.	(Siriaraya & Ang, 2012a)
6	Special issue on presence and interaction, Interacting with computers, Journal (2012)	Age differences in the perception of social presence in the use of 3D virtual world for social interaction.	(Siriaraya & Ang, 2012b)

Table 1: A list of publications arising directly from this PhD thesis

1.5 Scope

The definitions and scope of many of the key concepts this thesis is based upon are still widely debated. One example is the concept of virtual worlds. The definition of virtual worlds in this thesis includes both goal oriented virtual worlds (such as massively multiplayer online games) and social oriented virtual worlds (such as Second Life). This study excludes virtual worlds created by virtual reality devices and focuses on desktop based virtual environments (see section 2.3 for a concrete definition). In addition, although healthy aging is a concept which has many facets, this study focuses on a definition based on Rowe and Kahn's model of successful aging (see section 2.2). It should also be noted that the goal of this thesis is not to directly prove the impact virtual worlds have on healthy aging. Such a topic would require specialities in healthcare which is beyond the scope of this research. Instead, this thesis focuses on investigating how virtual worlds could be better designed to provide activities with qualities (based on pre-established theories) that have been found to be beneficial in supporting healthy aging.

This thesis also focuses on older people of a certain age range. Researchers in the field of gerontology have classified older people into cohorts such as the pre-senior (50-64), young old (65-74), middle old (75-84) and old-old (85-90) (see section 2.1.1). The main bulk of the participants in this study are those in the pre-senior and young old age ranges. The rational for selecting this age range is that these users would likely be familiar enough with

technology due to the cohort effect of aging and would not be too bogged down with issues of ICT literacy when they interact with virtual world technology. Users in this age group would also likely be those who benefit from this technology as they grow older. See section 2.1.1 for more details about the criteria of old age selected for this thesis.

Although, accessibility issues are important in research which explores the use of technology by older people, such issues are not the main focus in this thesis. The main focus of this thesis is on exploring the interaction and behaviour of older people in virtual worlds. In Chapter 5, during the development of the virtual world system, usability tests were carried out to address some of these accessibility issues. However, the main goal of these tests were not to generate a definitive guideline on designing accessible virtual worlds, but rather to ensure that older people with minimal computer experience are able to successfully use the virtual environments to complete the task.

1.6 Structure

The structure of the thesis is as follows:

- In chapter 2, a review of literature on the topics related to this thesis is presented. First, the elements which are central to the thesis, namely "virtual worlds", "older people" and "healthy aging" are discussed. Afterwards, the use of computer technology in supporting older people is examined along with a section suggesting how virtual worlds could be used to support healthy aging for older people. At the end of the chapter, key concepts on user behaviour and interaction in 3D virtual environments are discussed.

- In Chapter 3, the results from an exploratory interview study are presented. Themes were created to illustrate key findings on the characteristics of older users and how they used virtual worlds. These themes were then analyzed in relation to Rowe and Kahn's model of healthy aging to show the potential areas in which virtual worlds could be valuable in supporting healthy aging. The findings suggested that virtual worlds could help mitigate the effect of disease and disabilities, facilitate social engagement (create deep relationships etc) and provide opportunities for carrying out productive activities and opportunities for mental stimulation.

- Chapter 4 extends on the exploratory study in the previous chapter and provides a quantitative analysis of the characteristics and interaction patterns of older people in 3D virtual worlds. Data from approximately 2500 online profiles of older users were collected and analyzed in comparison to online profiles of younger users. The results show several distinct patterns (social network patterns, etc.) and characteristics of older virtual world users. For instance, older users were found to have a smaller number of ties but had higher levels of interaction between each tie when compared with younger users. Older users were also found to be interested in participating in groups which have activities which augment their physical lives.

The later part of the thesis would focus more on the social interaction aspect of older users in 3D virtual worlds.

- Chapter 5 describes the design, development and testing of a virtual world system which is accessible and easy enough for older users not familiar with computers to use. The process used in the design and development of this system provides a methodological contribution to those looking to develop 3D virtual environments for older users. This system was then used to carry out experiment studies in the following chapters.

- Chapter 6 discusses the results from a virtual island study in which 60 users (30 old and 30 young) were paired up and asked to visit a virtual island to carry out a social interaction task. Age differences between older and younger users in a number of factors such as physical and social presence were analyzed along with non verbal social behaviours such as Proxemics. Older users reported lower levels of social presence than younger users and had more difficulty navigating in the virtual world. Older users were also found to display proxemic behaviour in the virtual world which is more similar to behaviour in the physical world when compared with younger users. In addition, different factors were found to be correlated with the quality of social interaction measures for older and younger users.

- In Chapter 7, the results from a virtual store study are presented. In this study, 38 older users were paired up and asked to carry out a social interaction task in two virtual stores. Both qualitative and quantitative research methods were used to present an in-depth analysis of what factors influence older user's social interaction experience in a 3D virtual world. Physical presence and navigation were found to influence social interaction. However, the avatar was found to be of limited use due to the limitations in the expression of non verbal communication and the difficulties in associating the virtual avatars with physical world people.

- Chapter 8 discusses the overall findings and implications from the four studies which have been carried out. The themes identified from interviewing older virtual world users in chapter 3 and the analysis of their activities and interaction patterns from the user profiles in chapter 4, were synthesised to provide an illustration of how older people use virtual worlds. This finding provides a theoretical contribution by extending knowledge related to computer use among older people in the context of virtual worlds. In addition, the results from the experiment studies (such as how the avatar and navigation influence social interaction) have been further analyzed and suggestions are provided to improve social interaction in virtual worlds for older people. Finally, suggestions are presented on how virtual environments could be designed to better support healthy aging. Both of these help provide practical contributions to designers looking to create virtual worlds which would be beneficial to older users. Chapter 9 presents a summary and discusses directions for future work.

Chapter 2: Literature Review

The literature review section focuses on a range of topics related to the key components of the research topic in this thesis. First, literature on the three main components in this thesis, namely "older people", "healthy aging" and "virtual worlds" were reviewed, mainly to define their meanings and scope within the context of this PhD. Then, the relationship between older people and computer technology in general is investigated. Examples of studies which have adopted technologies with similar features as virtual worlds to support older people are emphasized. The relationship between virtual worlds and healthy aging is then explored. Afterwards, studies related to user interaction and behaviour in virtual worlds are described.

2.1 Older people

The first section focuses on the definition of old age and the main implications of the aging society.

2.1.1 At what age can one be defined as "old"?

The criteria of how old one must be to be classified as an "older person", "senior citizen", or "elderly person" is often disputed, between cultures, nations and in some cases between institutions and discipline. Before the introduction of retirement age and pension schemes, the definition of old age was subjective, often referring to the age where "one ceases to become independent either economically or physically" (Vincent, 2003). Nowadays, with the introduction of pension schemes, governments seem to base their cut off age for older people as the age where one becomes eligible to receive pension benefit, which is usually 60+ or 65+ years (World health Organisation, 2010). International institutions like the UN, on the other hand, consider those aged 60 and above as an older person (UN , 2007).

In academic research, some researchers in the field of gerontology have classified older people into cohorts based on similarities in experience and characteristics. Older people have been classified into cohorts such as the young old (aged 65-74), middle old (75-84), old-old (85-90) and even the very old (those who are centenarians) (See (Getzel & Mellor, 1985)). For studies in Human-computer Interaction (HCI), there does not seem to be a standard criterion for old age. Certain studies investigating the use of computers by older people have included those as young as 50 (which they referred to as the pre-senior age range (50-64)) (Lee, Chen, & Hewitt, 2011). Studies investigating the interaction of older people with novel computer technologies also accept relatively young older participants. For example, studies looking into the use of social network sites accepted those aged 58 and above (Lehtinen, Nasanen, & Sarvas, 2009) or aged 60 and above (Pfeil, Arjan, & Zaphiris, 2009)). Another studying investigating navigation in 3D environments selected participants who were older than 61 years (Sjolinder, Hook, Nilsson, & Andersson, 2005).

3D virtual worlds are still a relatively new technology even for the majority of young computer users. Interaction with this technology often requires considerable skills in cognition and IT knowledge. Therefore, a relatively young age range was chosen as the criteria of "older people" in this PhD research. The age criteria for older people in this thesis is ***55 years or older***. The selection of this age range would mean that those in the pre-senior age group (55-65) would also be included in the studies carried out in this PhD work. Although it might seem that people in this age range are relatively young to be considered as "older people", I believe that such users will become the main group of the future generation of older people who engage with virtual worlds and would most benefits from this technology in healthy aging as they grow older. Due to the cohort effect of aging, such users are likely to already be familiar with many forms of computer technology (Jones & Fox, 2009) and would thus be more receptive towards experimenting with newer technologies (Ellis & Allaire, 1999) (Karavidas, Lim, & Katsikas, 2005). Choosing users with adequate computer skills would enable the researcher to focus more on the core interactions and behaviour exhibited in the virtual world platform without becoming too bogged down with issues of ICT literacy and basic usability.

It should also be noted that the aging process is often multi-dimensional. In addition to the cognitive and physical changes (discussed further in section 2.4.2), a number of social and psychological changes accompanies a person as they age. For instance, as a person ages, there is an increasing likelihood that the person's social network would decline (See (Singh & Misra, 2009)). The change in one's social role from a working person to a retired person would mean less chance for social interaction. Declines in the person's physical ability could also lead to an inability to participate in social activities. Also, most people in this age range experience the loss of friends and family members due to old age. Therefore, loneliness is a prevalent issue with older people which could lead to problems such as depression (Singh & Misra, 2009). In addition, age related changes could also lead to a decline in self esteem (Robins et al, 2002). Changes in one's social-economical status and increasing cognitive and physical impairments have been cited as possible factors for this decline (see (Robins et al, 2002)). People in this generation also experience a loss in social power and an increasing need to be dependent on others (Vincent, 2003).

Therefore, the process of aging is not only a physiological process, but also has with it many social and psychological transitions. Much of this could influence how older people use and interact with computer technology. Even though relatively young older participants were included in this thesis, (participants who could be in relatively good physiological health) many of them would be starting to go through the social and psychological transitions mentioned above. They would also likely begin to suffer from the problems associated with these transitions. As such, including such participants would be beneficial as it would provide valuable insight into how virtual worlds could be designed to facilitate a healthier aging process.

One of the reasons older people are the focus for this study was because in recent years, the proportion of the older population began to increase significantly. This phenomenon is often referred to as the aging of the society. To provide further context for the motivation of my research, the next section would expand more on this phenomenon.

2.1.2 The Aging of society and increasing importance of older people to society

Reports and research literature on global demographics trends from a number of sources agree that world's population is aging (UN , 2007), (European Commission, 2007), (US Census Bureau, 2009). (Darnton-Hill, 1995). These demographic changes are thought to have major consequences and implementations to future services such as in healthcare. A UN population report (2007) predicted that in 2050, there would only be 4 people working to support one retired person, a significant drop from the current ratio 12. This shows how there is a need to find innovative solutions to enable older people to lead more active and healthier lives. Another impact from the aging of society is the increasing significance of older people to the economy. Older people represent a growing consumer groups which commands considerable purchasing power (UNECE, 2009), (Eastman & Iyer, 2004) (Wong, 2006). As such, there is also a financial incentive for businesses and companies to develop and improve existing products and services to better cater to the needs of older people.

This thesis proposes that virtual worlds could be used in this role and aims to lay the ground work to determine how such systems could be designed more appropriately for older people, especially to support healthy aging. However, in order to accomplish such a goal, it would first be necessary to identify what healthy aging is and what are the contributing factors.

2.2 Healthy Aging

Advances in medicine have led to the substantial increase in life expectancy, allowing people to live much longer lives than before. During this period, gerontologist began to redefine what it meant to age successfully. Previously, it was usually believed that disease and disability from the aging process was genetically determined and prior definitions usually distinguish healthy aging based on whether the person was suffering from disease, disability or neither (Rowe & Kahn, 1997). However, in 1987, Rowe and Kahn distinguished the groups of non diseased older people into the usual agers (non diseased but high risk) and the successful agers (low risk and high function) (Rowe & Kahn, 1987). Afterwards, based on this concept and subsequent research on the characteristics of aging successfully, Rowe and Kahn proposed a conceptual model to define successful aging (See Figure 1) (Rowe & Kahn, 1997). In his model, successful aging constitutes of three main components, a low probability of disease and disability, high cognitive function (both physical and cognitive) and an active engagement with life (good interpersonal relationships and participation in productive activities).

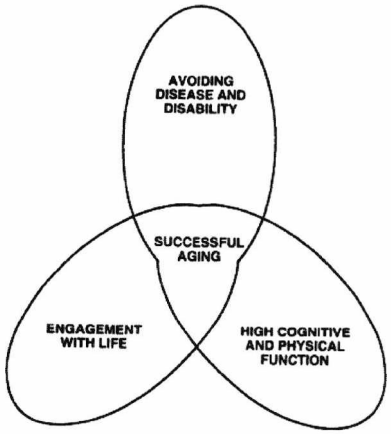


Figure 1: The model of successful aging proposed by Rowe and Kahn

Even today, this model is widely accepted by researchers and health professionals (Bowling & Dieppe, 2005), (Depp & Jeste, 2006). Various studies have also argued for similar components for healthy aging. For example, cognitive engagement and mental stimulations were mentioned by Batles & Batles (1990) as important factors in healthy aging. Social relationships, an important factor in engagement with life, have also been shown to be positively associated with health (House & Landis, 1988). Social supports from these relationships have been argued to help reduce stress and improve psychological wellbeing (Wright, 2000). Leisure and volunteering activities, which are examples of productive activities, have also been found to be beneficial to older people, helping improve well being ((Fratiglioni, Paillard-Borg, & Winblad, 2004), (Morrow-Howell & al, 2003)).

Researchers in other fields however have their own opinions on what constitute healthy aging. A recent publication offered a comprehensive review into the definition of healthy aging based on literature from the sociological and psychological fields in addition to the medical field. The review article argued that in addition to the factors already mentioned, factors such as life satisfaction, self worth, financial security, spirituality and learning new things are necessary for successful aging (for more details see (Bowling & Dieppe, 2005)). Bowling and Dieppe (2005) noted that successful aging should not be defined by all these criteria as it would be unrealistic but should be viewed more as an ideal state in a plain of continuum. They also emphasized that successful aging should be considered from multiple dimensions, not just by the medical models prevalent with health professionals.

International organizations and research institutes also often have similar definitions and opinions about the components of healthy aging for older people. A report in independent living for the aging society which was part of the i2010 strategy (An EU policy framework for the information society and media) pointed out that not only is the ability to live longer independently, but also the ability to continue to work and contribute productively and the ability to actively participate in society are essential to a high quality of life for older people (European Commission, 2007). Meanwhile, a WHO scientific group offered a concise

definition and proposed "*the maintenance of autonomy as the basic aim of healthy aging and prevention of its loss as the objective of any invention programs*" (Darnton-Hill, 1995).

According to the literatures reviewed, it is clear that there are diverse opinions on the criteria for healthy aging. Building on Bowling and Dieppe's review paper (2005), a simple table summarizing the various components for healthy (or successful) ageing based on the literatures reviewed has been constructed (Table 2).

<table>
<tr><th colspan="2">Individual</th><th>Social</th></tr>
<tr><th>Bio-medical</th><th>Psychological</th><th></th></tr>
<tr><td>The absences of disease</td><td>Life satisfaction (satisfaction of one's past and present life, self worth)</td><td>Able to actively participate in social activities</td></tr>
<tr><td>High cognitive functioning (The absence of mental disabilities)</td><td>Independence (Self efficacy, autonomy)</td><td>Functional resources and financial security</td></tr>
<tr><td rowspan="3">High physical functioning (The absence of physical disabilities)</td><td rowspan="3">Spiritual Satisfaction</td><td>Able to contribute productively to society (such as volunteering, etc.)</td></tr>
<tr><td>Able to learn new things</td></tr>
<tr><td>Strong Social Relationships and support network</td></tr>
</table>

Table 2: The components of healthy aging proposed by various researchers

For this thesis however, the criteria of healthy aging is based mainly on Rowe and Kahn's model of successful aging (Rowe & Kahn, 1997), due to the model's robustness and wide acceptance when compared to the definitions proposed by other researchers and institutions. In addition, even though there are many proposed theories and factors for healthy aging, Rowe and Kahn's model is more suited for assessing the value of virtual worlds in supporting older people as this model provides an assessment of healthy aging based on multiple distinct dimensions rather than on a single dimension (such as based only on bio-medical factors). Section 2.5.5 provides examples on how virtual worlds could be used to support healthy aging based on this model.

In summary, I focus on the following criteria for healthy aging in this thesis:

1. Continued and Active engagement with life: this includes, as defined by Rowe & Kahn's model of healthy aging, maintaining strong interpersonal relationships and active participation in productive activities. Adequate satisfaction with life is also included.

2. Upkeep of cognitive and physical functionality: having a high level of physical and cognitive functionality, able to maintain a sufficient level of autonomy for independent living.

3. Absence of disease and disability: Reduced risk for disease and disabilities. This could also mean the reduction of negative effects caused by disability and diseases.

2.3 Virtual worlds

The next component investigated in this literature review is related to the virtual world technology itself. When the word "virtual worlds" is mentioned, people often conjure the image of a vast 3D environment accessible through the computer screen, existing as either platforms for play such as World of Warcraft[1], Everquest[2] and Star wars galaxies[3] or existing as platforms for social interaction such as Second Life[4] or IMVU[5] (Please refer to Appendix A for the details of the virtual worlds mentioned in this thesis). This is not surprising, as such massively multiplayer online virtual environments (MMOVEs) have enjoyed continuous growth both in popularity and variety in recent years. The reason for this growth include factors such as an increase in high-speed internet penetration, the growth of age cohorts familiar with gaming and an increase in graphical realism from more powerful personal computers (Castronova, 2005). Although these MMOVEs share many similarities, not all scholars believe they should be referred to as virtual worlds. Researchers have proposed many criteria which they argue to be necessary for the definitions of "true" virtual worlds.

This section begins by first constructing a definition of virtual worlds based on the criteria proposed by previous researchers. Then, the current state of virtual world technology along with the characteristics and functionalities of virtual worlds which are available at the time this thesis was written are discussed.

[1] http://eu.battle.net/wow/en/
[2] http://www.everquest.com/
[3] http://www.swgalaxies.net/
[4] http://secondlife.com/
[5] http://www.imvu.com/

2.3.1 The definition of Virtual Worlds

Virtual worlds are mostly seen to be a computer simulated environment where multiple users can enter simultaneously and interact with one another. Researchers proposed a number of criteria which distinguish virtual worlds from other online spaces. They argued that virtual worlds should be persistence, shared by a large number of users and interactions taking place inside them are fed back in real time to users who are represented in-world by a single game entity ((Castronova & al, 2007), (Bartle, 2004), (Bell, 2008)). Some definitions of virtual words specify that the interaction of players must be mediated through characters known as avatars (Norris, 2009). Other researchers find user editable content (Boulos, Ramloll, Jones, & Toth-Cohen, 2008), 3D graphical representation and a community to be necessary components of virtual worlds (Sivan, 2008). Virtual worlds are also sometimes known by other names such as immersive worlds, immersive virtual worlds, synthetic worlds and simulated worlds ((Castronova, 2005) , (Freitas, 2008)).

The distinction between online games and virtual worlds is also often under debate. Some researchers have chosen to exclude online game spaces such as Massively Multiplayer Online Games (MMOG) from the definition of virtual worlds entirely (Spence, 2008), while others have argued against the fallacy of such distinction. These researchers argue that strong social engagement elements could be found in many online games and game-like activities also often emerge in social-based virtual worlds. Therefore, they argue that there is no real difference between the two spaces (Metaverse Roadmap, 2007).

The definition of virtual worlds in this PhD thesis was constructed based on the conventions of virtual worlds which are agreed on by most researchers. Within the context of this thesis, I define virtual worlds as:

"Persistent virtual environments which contain representation of real or fictional places that multiple people can inhabit and interact in real time through the use of their avatars."

Based on this definition, all forms of MMOGs (2D or 3D), multi-user domains (MUDs) and chat-virtual world hybrids are considered as virtual worlds. The definition proposed in this thesis may seem broad when compared to other definitions; however, they incorporate the core features of virtual worlds which have existed historically even though their forms might have changed following the improvements of technology. For instance, earlier virtual worlds (Multi-user domains) used textual narratives to represent the environment, user avatars and the interaction within the virtual worlds (Curtis, 1992). However, as the processing power of computers increased, textual avatars and environments were gradually replaced with 2D and then 3D ones. Even though their visual forms might have been changed, their roles in virtual worlds still remain the same. Therefore, by defining virtual worlds based on these core components, I believe that the findings from this thesis would be more useful to a wider range of virtual world systems and would more likely remain applicable to future generations of virtual worlds.

2.3.2 The Current State of virtual worlds today

Following the increase in the processing power of computers, virtual worlds today are being represented by increasingly complex graphical forms. Virtual worlds evolved from simple text based multi-user environments (MUDs) to more complex platforms where objects were represented with 2D images and then later to platforms which adopted increasingly realistic 3D graphics. While earlier virtual worlds often took the form of online role playing games (Curtis, 1992), later virtual worlds were more open-ended, some even created with the aim of being used as a platform for social interaction (such as Habitat[6]) (Taylor T. L., 2006). Virtual worlds today have become even more multi-functional, with features that allow for user generated content and in-world commerce (Sivan, 2008). Such platforms have drawn in large communities of users and are predicted to draw in even more in the future (Castronova, 2005).

Gathering data about the exact size of the virtual worlds existing today is not an easy task, as such data is usually regarded as a trade secret by commercial virtual world providers (Spence, 2008). Most data obtainable is from secondary data sources usually found in press releases or publications from consulting firms. One recent survey done by KZero (a consulting company dealing with virtual worlds, virtual goods and 3D gaming) identified over ninety commercial virtual worlds existing in 2008 (see (Spence, 2008)). This survey did not even include most of the virtual worlds designed for gaming purposes, which usually draw in large communities of users from all around the world. One example of a popular Massively Multiplayer online role playing game (MMORPG) is World of Warcraft which has reached more than 11.5 million subscribers as of 2008 (Blizzard Entertainment, 2008). Overall, the evidence gathered points towards a large and growing number of online virtual worlds existing in the market today.

One notable virtual world still popular today is Second Life (formerly Linden World) which went live in 2003. Second Life was developed by Linden Labs with the aim to encourage user-generated experience and content (Second Life History, 2012). It was estimated that in just one month (December 2009), Second Life was host to more than 770,000 unique users with repeated logins. Second Life is also one of the first virtual worlds to implement a successful economic model where users can sell objects they created inside the virtual world for physical world money. Gross Residential earnings (The amount of money which was transferred from Second Life to real world bank accounts of residents) valued no less than $55 million in 2009 (Linden, 2010). Second Life has also received considerable attention by practitioners and professionals in various fields who are looking to use virtual worlds in more serious contexts such as in healthcare and education ((Boulos, Hetheringon, & Wheeler, 2007), (Freitas, 2008)).

Second Life contains all the features which have been used to define the paradigm for "true virtual worlds", namely 3D environment, community, creation and commerce (Sivan, 2008).

[6] Virtual world is currently defunct. Data related to this virtual world is obtained from (Morningstar, Farmer, & Researchers, 2008)

Other types of virtual worlds which do not completely adhere to such principles have also emerged (such as IMVU etc). This shows how there are different aspects to interaction in virtual worlds. In the next section, some of these aspects and the different types of virtual worlds existing today are explored.

2.3.3 The types and aspects of virtual worlds

To provide a clearer understanding of the types of virtual worlds existing in the market, researchers have offered various classifications of virtual worlds based on their characteristics (goal-oriented or open-ended) or targeted uses (Socializing, Entertainment etc). From these classifications, three applications of virtual worlds could be derived. Each application represents a different functionality virtual worlds can offer for users. The characteristics of the types of virtual worlds which represent each application would be explained and examples of existing online virtual worlds which provide these applications would be given.

2.3.3.1 Goal oriented virtual worlds (Gaming application)

Virtual worlds have been divided into goal-oriented virtual worlds and social virtual worlds (Metaverse Roadmap, 2007). Goal-oriented virtual worlds take the form of massively multiplayer online role-playing games where users are set in a fictional or fantasy space and tries to complete pre-determine tasks to obtain rewards. As users spend more time in these worlds, they usually increase in both power and status from these rewards. Examples of such virtual worlds include Everquest, Star wars Galaxies and World of Warcraft. Other types of goal oriented virtual worlds which do not focus on fantasy or science fiction role-playing are also beginning to emerge. For instance, in empire of sports[7] (See Figure 2 for a screenshot), users can participant in a variety of sporting events and compete with others online. Goal-oriented virtual worlds can provide interactive game play similar to many computer games seen today. One can argue that such virtual world have their roots from small scale multiplayer games and evolved to host larger communities of players, adding social engagement to their previous game play factors.

[7] https://www.empireofsports.com/en/index.html

Figure 2: A screenshot of the gaming virtual world Empire of Sports. The user is currently competing in Tennis.

2.3.3.2 Social virtual worlds (Online community application)

Social virtual worlds in comparison to goal oriented virtual worlds, are more open ended and contain fewer goals and value structures. In such worlds, factors such as social interaction, creation of in world objects and interpersonal relationships are more emphasized (Metaverse Roadmap, 2007). Virtual worlds such as these usually serve the function of "third places", or "*Public spaces where one shares leisure and social spaces with other people*" (Spence, 2008). Researchers have also found strong interpersonal relationships and immersive social engagement emerging from such virtual worlds (Winder, 2008), (Boellstorff, 2008).

Examples of these types of virtual worlds include IMVU, an avatar-based social networking and instant messaging service utilizing a 3D virtual environment (IMVU, 2011) and more open-ended virtual worlds such as Active worlds[8] (see Figure 3 for a screenshot), There[9] and Second Life. From their characteristics and the functionalities they serve, these types of virtual worlds might be considered as an improved form of online communities, having evolved from computer mediated communication tools such as E-mails, online web forums or messenger programs. Virtual worlds such as these are able to enrich social interaction for users.

[8] http://www.activeworlds.com/
[9] http://www.there.com/

Figure 3: A screenshot of Active worlds

2.3.3.3 Information providing virtual worlds (Information & Services provision application)

Not all virtual worlds are constructed based on alternative realities. A mirror world is a virtual world which is constructed based on our physical world using sophisticated mapping technologies, ground based imagery from satellites or scanning cameras. These worlds have been used in areas such as business analysis, geopolitics, simulation and navigation, usually to provide information and visualization about a geospatial area (Metaverse Roadmap, 2007). Some virtual worlds, such as Twinity[10] (See Figure 4 for a screenshot), are constructed as a 3D mirror world based on real city maps but are also hosts to online communities, playing both the role of a mirror world and a social virtual world (metaversum, 2010). Such virtual worlds have the potential to present useful information about the physical world, merging it with interactive social engagement.

[10] http://www.twinity.com

Figure 4: A screenshot of the virtual world Twinity, showing a virtual replica of New York Times square.

Some open ended virtual worlds could also be used to provide information similar to that of the internet. There have been projects which have investigated how virtual worlds such as Second Life could be used to present health information interactively (Boulos, Hetheringon, & Wheeler, 2007). As such, some researchers have argued how virtual worlds could become a role model for the development of the next generation of the internet (Metaverse Roadmap, 2007).

As discussed earlier, there are three applications of virtual worlds, namely information & services provision, online communities and gaming. A diagram was constructed to summarize those applications and examples of virtual worlds which are representative of them are given. The diagram is shown in Figure 5.

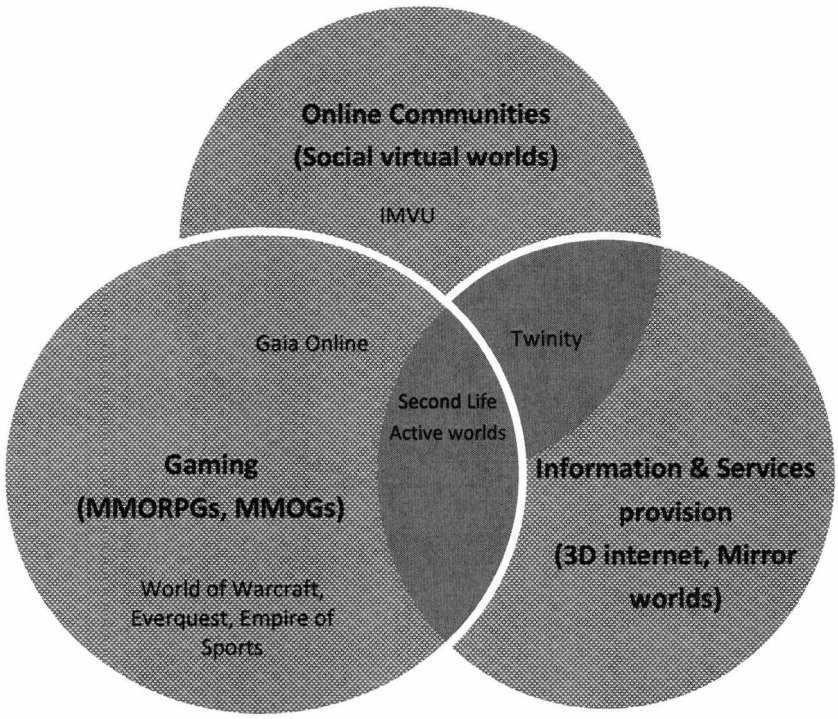


Figure 5: The applications of virtual worlds and examples of virtual worlds representative of those applications

2.4 Older people and computer technology

In the previous sections, studies related to the core concepts of this thesis, namely, older people, healthy aging and virtual worlds have been reviewed and a definition and scope for each of these terms has been proposed. The following sections focus on older people's use of computer technology. This section discusses how older people engage with computer technology, in particular, online technology.

2.4.1 Older people and online technology

Recent surveys and studies have shown that older people are using online technology for a variety of purposes. Older people use the internet for tasks such as shopping, searching for medical information and receiving news about current events (Eastman & Iyer, 2004). More recently, an increasing number of older users are beginning to participate in online activities which have been traditionally popular with younger users such as using social network sites, listening to music and watching videos (Pew Research Center, 2010a). The most common use of online technology by these users however, seems to be in the context of social interaction (Wagner, Hassanein, & Head, 2010). Older people are also using social media such as Twitter and Facebook as a tool to connect with past friends (Pew Research Center, 2010b).

Studies have also shown that older people engage with technology in a different manner when compared with the younger generation. Much of this can be seen from the differences in the type of online activities carried out between older and younger people. For instance, surveys carried out by the Pew Research center(2010a) show that younger adults (aged 18-33) are more likely to use social network sites (83%), play online games (50%) and visit blogs (43%) than older adults (34% of older adults aged between 65-73 use social networking sites, 25% play online games and 23% visit blogs). According to this survey, activities such as using Email (90% for older adults aged 65-73 and 96% for those aged 18-33), looking for health information (76% for older adults aged 65-73 and 85% for those aged 18-33) and making online purchases (59% for older adults aged 65-73 and 68% for those aged 18-33) are common for both older and younger adults. However, a larger percentage of older users participate in activities such as searching for financial information when compared with younger adults (44% for older adults aged 65-73 and 33% for those aged 18-33) (Pew Research Center, 2010a). Studies also show that some of the differences in the interaction patterns displayed by older people as they engage with computer technology could be attributed to their unique characteristics. One example showed how older people used past stories and memories to help bond with each other in an online mailing list community (Kanayama, 2003). Another example is in the creation of online content. Older people were found to be interested in creating content based on past experience of themselves and their community (Karahasanovic & al, 2009). Analysis of old and young users of social networking sites also show differences in the nature of the users' networks of friends (Pfeil, Arjan, & Zaphiris, 2009). Key differences were also identified between Usenet newsgroups used by teens and older adults. For instance, Zaphiris & Sarwar (2006) found that the social network of teens in Usenet was more connected to each other while that of older adults was more focused and relied on a number of key members. Topics popular with senior newsgroups include topics such as retirement, military, culture and health. Teens however preferred topics such as abortion, religion, parents and music (Zaphiris & Sarwar, 2006).

2.4.2 Effect of older users characteristics on their use of computer technology

A number of studies have shown how the unique characteristics of older people (such as having reduced physical and cognitive ability etc) had an impact on their ability to interact with computer technology. These studies show that even though older people are able to learn how to use computer technology, they do so at a slower pace and with a lower performance level compared to younger users (Czaja & Lee, 2007). Part of this could be attributed to declines in functionality which occurs naturally as a process of aging. For instance, declines in sensory and motor skills have been argued to have an impact on the ability of older people to obtain visual information from the computer screen and their ability to interact with input devices, which could be one reason for their lower performance (Czaja & Lee, 2007). Similarly, Dyck & Smith (1996) found that differences in cognitive abilities such as spatial scanning ability, logical deductive and inductive reasoning impacted older people's ability to acquire world processing skills. Freudenthal (2001) also found that spatial ability and reasoning speed affected performance on information retrieval tasks.

Apart from this, because older people have less experience with computers from their workplace, they could feel uncomfortable engaging with this technology. Psychological factors such as computer anxiety have been frequently cited as a barrier to the acceptance of computer technology ((Phang, Sutanto, Kankanhalli, Li, Tan, & Teo, 2006), (Jung et al, 2010), (Mallenius, Rossi, & Tuunainen, 2007))). Previous studies have argued how high levels of computer anxiety could affect a user's computer performance (Mahar, Henderson, & Deane, 1997). Wagner et al. (2010)'s review of literature on computer use by older adults also discusses other barriers such as how some older users had negative attitudes towards technology or felt alienated or too old to learn about technology. Apart from this, other factors such as the lack of perceived benefit, the lack of knowledge and interest in computer technology and to a minor degree financial costs have also been cited as reasons why older people do not adopt new computer technologies (Melenhorst, Rogers, & Bouwhuis, 2006), (Peacock & Ku¨nemund, 2007).

Due to these unique characteristics of older adults, researchers have proposed various guidelines on designing technology for users of this age group. To address the physical and cognitive declines, guidelines have been proposed to improve the design of software interfaces (Wirtz et al, 2009), websites (Kurniawan & Zaphiris, 2005) and digital games (Ijsselsteijn, 2007) to make them more accessible to older users. Design methodologies such as inclusive and universal design have also been proposed, which aims to develop software which is accessible to as many user groups as possible (see (Newell, 2008)). Some researchers however have argued against such processes as designing products to address the disabilities or attributes of certain user populations could hinder the use of the product for other users or lead to significant increases in development costs ((Newell, 2008), (Newell & Gregor, 2000)). These researchers felt it would be near to impossible to create a sample group and design a product which is universally accessible (Newell & Gregor, 2000). Instead, they argue for "User-sensitive Inclusive design" as a design goal and believe that designers should focus on a number of "extra-ordinary" users who are potential users of the product and design to address these individuals' particular needs. For instance, with older users, the designer would be given examples of individuals possessing particular characteristics (i.e. specific disabilities which have been found to be relevant to the system) and would need to come up with design solutions to address the requirements of these particular users. Afterwards, the various designs would be integrated into the final design (Pullin & Newell, 2007).

2.5 Computer technology in support of healthy aging

The previous section has discussed how older people engage with computer technology. This section focuses on the relationship between technology and healthy aging. In particular, this section examines how computer technologies with similar functionalities to virtual worlds have been used to facilitate healthy aging.

A number of different technologies have been used to help improve the quality of life for older people. To enable the increasing older population to live an independent and healthier

life, technologies such as health monitoring garments, intelligent mobile devices, smart homes (European Commission, 2007) and personal service robots (Roy & al, 2000) have been developed. Contrary to popular stereotypes, older people could be receptive of such technologies if they are perceived to be beneficial (Czaja & Lee, 2007). Therefore, technologies such as these could play a key part in the care of older people in the near future.

To provide clues on how virtual worlds could be beneficial in supporting healthy aging, this section looks at how technologies which have similar functionalities as virtual worlds (see section 2.3.3) have been beneficial for older people. The benefits older people could gain from using technologies such as the internet, web based online communities and computer games are discussed.

2.5.1 The use of the information and service providing functionality of the internet to support healthy aging

Various studies have cited the benefits older people can gain from using the internet. For instance, Czaja and Lee (2007) argued that the internet can allow older people to work flexibly from their homes, provide access to life-long learning, facilitate access to health information and improve care giving services. The usage of the internet has been shown to help reduce feelings of isolation and improve self-confidence (Blit-Cohen & Litwin, 2004). This technology could also help increase the efficiency of tasks in daily life for older people (Karavidas, Lim, & Katsikas, 2005). Such tasks include shopping, travel reservation and banking (Jones & Fox, 2009). Blit-Cohen (2004) also argues that the frequent updates about local events and the news provided by the internet enable older people to not feel excluded from mainstream society. Internet usage surveys have found that seeking information on health related topics was the second most common activity for older people (Eastman & Iyer, 2004), suggesting that older people are interested in using the internet to obtain more information to care for their health.

2.5.2 The use of web-based online communities to support healthy aging

Online communities in the form of web-based forums could also be beneficial in supporting healthy aging for older people. A study carried out by Pfeil et al (2009) shows that older users had received emotional support from these online communities and were able to develop deep interpersonal relationships. Emotional support from these communities has been especially valued by older people whose illness restricts their ability to meet people offline (Pfeil U. , 2009). In addition, the anonymity from these mediums also encourage a high level of self disclosure which helps negate the uncomfortable feeling of asking for help offline (Pfeil & Zaphiris, 2007), (Pfeil U. , 2009). Another study which observed messages exchanged on an e-mail list service for seniors in Japan found a similar trend in that users were able to develop companionship and supportive relationships (Kanayama, 2003). These companionship networks have been argued to serve the same function as "weak tie" relationships which help older people feel more integrated with society (Wright, 2000). Such companionship networks also play a role in sustaining emotional well-being and buffering stress for older people (Rook, 1987).

2.5.3 The use of computer games to support healthy aging

There has also been considerable interest in the use of computer and console games to help prevent the cognitive declines of older people. One gaming project known as Eldergames[11] was established to develop games which not only prevent the negative effects related to aging (declines in memory, cognitive functionality etc), but also detect early signs of social and cognitive problems for older people. Another example of a game popular with older people is a mental stimulation game called "Dr. Kawashima's Brain Training game[12]" which is a Nintendo DS console game. This game gives players puzzles and quizzes to solve to help stimulate their memory and attention (Ijsselsteijn, 2007).

A growing body of evidence also suggests that common video games in the market may also have beneficial therapeutic effects for older people (Griffiths, 2005). Apart from being a recreational activity, computer games could help in comprehension, memory and help increase attention span and hand-eye coordination (Watering, 2005). Older people who actively use video games also show a slower rate of intellectual decline (Farris, Bates, Resnick, & Stabler, 1994) and have improved self esteem (McGuire, 1986). Newly created gaming consoles such as the Nintendo Wii were also shown to be popular with older people (Wischnowsky, 2007) and such platforms offer the chance for older people to become more physically active while enjoying themselves.

2.5.4 The potential of virtual worlds in supporting healthy aging

The previous section has shown examples of how technologies with similar functionalities as virtual worlds have been useful in supporting older people. As shown earlier, by themselves, each of those three technologies has been argued to be valuable in supporting healthy aging. Virtual worlds however, have the potential to combine all the beneficial elements from these technologies (information & service provision, online communities and gaming) and offer an innovative solution to support healthy aging in a unique new way. Revisiting Rowe and Kahn's model of successful aging; I noticed that each component of healthy aging could be supported by one or more of the applications provided by virtual worlds.

- ***The information & service providing application*** of virtual worlds could help in the *avoidance of disease and disability.* For instance, health information could be presented interactively in the virtual world (Boulos, Ramloll, Jones, & Toth-Cohen, 2008). E-learning and knowledge cultivating activities (such as exhibitions in virtual museums) could also be implemented inside virtual worlds (see (Freitas, 2008), (Urban, 2007)). Participating in such activities could help *older people maintain a high cognitive function.* Similar to the internet, useful information and services (such as banking, shopping etc) could also be offered in virtual worlds and this would help *provide engagement with life for home bounded older users*.

[11] http://www.eldergames.eu/
[12] http://www.braintraining.com.au/

- **The online community application** of virtual worlds could provide social engagement for older people. Not only would this platform allow older users to meet new people, keep in touch with friends and exchange support in a similar manner to traditional web-based online communities, virtual worlds also allow older people to engage in social activities together with their friends in an environment which is highly immersive. These types of activities could allow older people to establish and strengthen social relationship more easily. Such forms of social engagement are considered to be an important component for *engagement with life.* Also, health support groups (a type of online support community) in virtual worlds could provide health related advice and support (Norris, 2009), helping older people *avoid age related disease and disability.* In addition, older people could also join intellectual communities, such as those hosting frequent debates, conferences, and quizzes. Participation in such communities would provide mental stimulation for older people and *help prevent cognitive declines.*

- **The gaming application** of virtual worlds could have the same therapeutic effects as computer games since they share many similarities in user engagement, narration and game play (Castronova & al, 2007). As such, regular usage of virtual worlds containing strong gaming elements might help *slow declines in cognitive functions* or help improve memory and hand-eye coordination for older people.

Building on Rowe and Kahn's model of healthy aging (Figure 1) and the diagram showing the applications of virtual worlds (Figure 5), a schematic summarizing the relationship between the applications of virtual worlds and the components of healthy aging they could potentially support was developed. This schematic is shown in Figure 6.

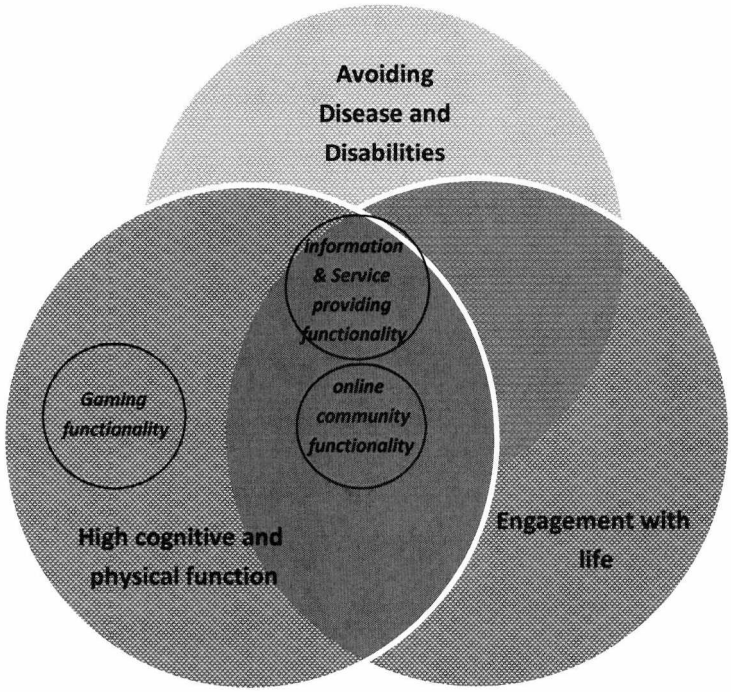


Figure 6 : The relationship between the applications of virtual worlds and the components of healthy aging they could potentially support

2.5.5 Examples of the beneficial uses of virtual worlds to support healthy aging

In the previous section, a schematic showing the potential areas in which virtual worlds could be used to support healthy aging has been described. Next, specific examples of how some activities already existing in online virtual worlds today have the potential to support healthy aging would be shown to provide further illustration.

2.5.5.1 Potential of virtual worlds in aiding healthcare

Virtual worlds could provide interactive and tailored health information to older users in the comfort of their own home. Virtual worlds such as Second Life offer many opportunities for these users to receive relevant health information. Older people looking for medical advice or general information about their health could visit the "*Consumer health library*" at Healthinfo island, a virtual island in Second Life which provides health related information and facilities for one-on-one support (Boulos, Hetheringon, & Wheeler, 2007). Several advantages of virtual worlds over the 2D web in providing information had been identified, such as the intuitive presentation of information through an interactive 3D environment and the social presence of other users during information seeking (Boulos, Ramloll, Jones, & Toth-Cohen, 2008) (Ostrander, 2008).

Virtual worlds are also host to a variety of healthcare support groups. Healthcare support groups in virtual worlds could be defined as, *"[a support group which] consists of a number of individuals that communicate health related supportive messages using the various features*

of their networked, persistence space through the use of their avatars" (Norris, 2009). A study conducted in 2009 found healthcare support groups on topics such as disability, depression and cancer existing in virtual worlds such as IMVU and Second Life (Norris, 2009). As such illnesses are common to people of old age, older people could benefit from the knowledge and emotional support by joining such groups.

The uses of virtual worlds in this context could be argued to indirectly help older people to *avoid disease and disability.* The accessibility of health information through this platform would encourage older people to live a healthier lifestyle and empower them to take a more active role in the healthcare process which could result in better medical outcomes (Czaja & Lee, 2007). Participation in healthcare support groups would also provide older people with social engagement, therefore improving their *engagement with life*.

2.5.5.2 Potential of virtual worlds as therapeutic tools

The use of virtual worlds as therapeutic tools is also starting to be explored. Virtual worlds have been used to help chronological ill patients overcome their physical ailments and participate in social activities. Participation in virtual worlds has also lessened depression and helped these users regain their social network (Kizelshteyn, 2008). Virtual worlds could also mask stereotypes in social interaction and present a feeling of empowerment for disabled users (Ford, 2001). Such platforms are also host to a variety of support groups for people with disabilities (Norris, 2009) and participation in such groups provide encouragement and emotional support.

Because of the many similarities in mobile and social constraints in everyday life between physically disabled people and home bounded older people, the therapeutic values and benefits presented could be similar for both groups of users. Virtual worlds could remove the restrictions and stereotypes (at least in the virtual environment) associated with being old, thereby reducing the negative consequences of their age and disabilities. In a sense, this kind of functionality of virtual worlds could be considered to help them *avoid the effects of their disability*.

2.5.5.3 Potential of Virtual worlds in cultivating skill and knowledge

Virtual worlds could also provide activities to engage and cultivate the skills and knowledge of older people (Freitas, 2008). Virtual worlds are host to a variety of classes, public discussions, seminars, conferences, and educational exhibits ((Jensen, 2009), (Bleacher & Stockman, 2008), (Boulos, Hetheringon, & Wheeler, 2007). Participating in these activities would allow older people to participate in life-long learning. Such activities would be invaluable for older people, especially those whose conditions restrict them from travelling to join such venues in the physical world.

Museums, traditionally seen as large establishments in physical spaces can now be seen in the virtual domains as places for interactive learning and social engagement. While some virtual museums are partial duplicates of their real world counterparts such as the Second

Louvre Museum, other virtual museums use multimedia technologies to display collections in a manner which provides rich interaction opportunities and is impossible to imitate in physical world museums. In such places, visitors can feel firsthand the effects of a tsunami, ride a virtual rocket into space or participate in a solar system simulation and watch as planets revolve around their virtual selves (Urban, 2007). Virtual museums such as these could provide invaluable opportunities for learning for older people.

The mental stimulation and cultivation of knowledge gained from participating in these activities could be argued to help *improve the cognitive functions* for older people. Participating in such activities would allow older people to acquire new skills and knowledge. This has been argued by Rowe and Kahn to be an important factor in *engagement with life.*

2.5.5.4 Potential of Virtual worlds as tools for communication and connectivity

Virtual worlds have also been used as tools to facilitate communication and collaboration. Castronova (2005) argues that although communication in virtual environments does not offer as rich a presence as videoconferencing, this form of communication uses less internet bandwidth and is able to present a richer 3D context of the user's environment. Virtual environments also provide opportunities for "side channel" communications such as gazes or gestures between non conversing group members which would be limited in video conferencing due to the lack of 3D spatial data (Bailenson, Beall, Loomis, Blascovich, & Turk, 2004). Apart from this, the 3D spatial data provided in virtual worlds could also offer a more diverse context for social interaction. Unlike video conferencing and text-based message tools, the embodiment of user interaction through avatars allows users to participate in social activities with other users (such as dancing) rather than just to communicate. These advantages might explain why studies have found that users are able to form strong interpersonal relationships through such platforms (Winder, 2008), (Gilbert, Murphy, & Avalos, 2011).

This use of virtual worlds to develop social relationships would be especially beneficial to older people who live alone. Indeed one could imagine such people using virtual worlds in the same way as other computer mediated communication tools, to expand and maintain their social network (Wright, 2000), reduce loneliness and receive support (Karavidas, Lim, & Katsikas, 2005). Usage of virtual worlds in such a way could be argued to help provide *engagement with life* for older people.

2.5.5.5 Potential of Virtual worlds as visualization tools for use in Tele-care

Researchers are also investigating the use of virtual worlds as visualization tools to provide information about older people to their caretakers and relatives. Second Life has been used to visualize information from collective wireless sensor networks, presenting caretakers with a high fidelity and intuitive visualization of older people in their living spaces (Boers, Chodos, Huang, Gburzynski, Nikolaidis, & Stroulia, 2009).Another example is the use of Second Life to visualize an older person's real world actions measured from an acoustic indoor and outdoor activity monitoring system to allow caretakers to monitor older people residing alone in an unobtrusive manner (Shaikh, Helmut, Hirose, & Mitsuru, 2009). Such visualization tools could

be combined with Tele-care systems and be used to help medical staff or family members monitor older people living alone to help them ***avoid disease and disability.***

2.5.5.6 Potential of virtual worlds in facilitating productive activities

Virtual worlds could also be useful in providing an avenue for older people, especially those limited in mobility, to participate in continued employment or work from the comfort of their own homes. Already, the business processes of some companies are embedded inside virtual worlds and such platforms are being used for internal meetings, conferences, collaborative design and knowledge exchange (Kaplan & Michael, 2009). The shortages of young adults in the workforce in the future would provide an important incentive for companies to employ people past retirement age (Darnton-Hill, 1995) and virtual worlds could be a useful tool to facilitate such processes. Encouraging older people to adopt such tools might not be as difficult as many people think, as older people are generally interested in making themselves useful to society, want to work with a flexible schedule and are not afraid of learning to use a new technology to enable them to do so (Czaja & Lee, 2007). Therefore, virtual worlds could be a useful tool in enabling older people to participate in productive activities such as continued employment after retirement.

Such activities have been argued to be a key component in successful aging (Rowe & Kahn, 1997) and generally help improve happiness, longevity and are also associated with larger social networks and better perceived health for older people (Darnton-Hill, 1995). Employers themselves would also benefit from the experience, advice and commitment of these elderly workers (Darnton-Hill, 1995). The use of virtual worlds in such a way would provide older people with opportunities to remain active and productive, an important component of *engagement with life.*

2.6 User behaviour in virtual world

In this section, literature related to user behaviour in virtual worlds is discussed. Even though virtual worlds have much potential in supporting healthy aging, badly designed virtual environments would discourage the participation of older users. To design more accommodating virtual environments, developers must take into consideration the unique characteristics, interests and behaviour of older people in virtual environments. However, there has not been much research conducted to directly explore the behaviour of older people in virtual worlds. Most studies focused on general users who are often young users familiar with technology.

Understanding these factors are one of the main research questions in this PhD thesis. Background knowledge about how general users behave and interact in virtual environments would accommodate us in accomplishing such a task. As such, in this section, literature has been drawn from various fields such as cyber psychology and Human Computer Interaction to explain what researchers have found regarding the interaction of typical users in virtual environments. Such knowledge would be useful as a framework to refer upon when studying

the behaviour and interaction of older people in virtual worlds.

Three key concepts: ***Presence***, ***Immersion*** and ***Selfhood*** are widely discussed in this field of research. Although, as stated previously, virtual worlds contain similar functionalities as traditional technologies (the internet, online communities and digital games), it is these three concepts of virtual worlds which enhances those functionalities and creates a unique experience for users.

2.6.1 Presence

The concept of presence has been widely used in many different contexts and has many broad definitions (See (Wirth et al, 2008), (Lombard & Ditton, 1997)). One description of presence proposed by Lombard and Ditton (1997) is "the perceptual illusion of non mediation". This refers to how well a system is able to provide users with an immersive experience to the extent that they fail to notice that there is a system mediating their experience. Presence could be conceptualized in many forms such as based on the feeling of transportation, (the feeling of being transported to an environment that is part of a story in a book or when watching a movie) or based on the perception of realism (Lombard & Ditton, 1997). In this thesis, I refer to the concept of presence mainly in the context of virtual environments. Presence is a recurring theme identified by various studies exploring behaviour and interaction in virtual environments. Researchers have further classified presence into social presence and physical presence. (IJsselsteijn, Ridder, Freeman, & Avons, 2000).

Social presence can be thought of as "the sense of being together with others" (see (Slater, Sadagic, & Usoh, 2000), (Zhao, 2003) (Biocca, Harms, & Burgoon, 2003)). For virtual world research, this usually refers to the extent that a user perceives to be with another user in the virtual environment. Another common definition of social presence in the context of mediated communication is related to how well a device can transmit non-verbal cues that are available in face-to-face interaction (Short, Ederyn, & Bruce, 1976). According to this definition, devices with higher levels of social presence (such as Video conferencing tools) are able to give more cues (facial gestures etc) than those with lower levels of social presence (such as a telephone call). Social presence is important to the design of virtual worlds as one of the key activities in virtual worlds is to carry out social interaction and construct meaningful relationships with other users (Boellstorff, 2008) (Zhou Z. , Jin, Vogel, Fang, & Chen, 2011). Virtual worlds which provide users with high levels of social presence can enhance these processes. Social presence can also be a useful indicator of the quality of communication in virtual environments (Garau, Slater, Vinayagamoorthy, Brogni, Steed, & Sasse, 2003). Another study has also found that the sense of presence can have an impact on a user's satisfaction with social virtual worlds (Jung, 2011).

Physical presence (or Tele-presence, Spatial presence) could be defined differently from social presence which was discussed earlier. While social presence is defined as the sense of being with others, physical presence can be thought of as the sense in which a user perceives

as being located in a place or environment (see (IJsselsteijn, Ridder, Freeman, & Avons, 2000), (Biocca, Harms, & Burgoon, 2003)). Wirth et al (2008) proposed a two-level model to help explain the formation of physical presence. In the first level, termed the "spatial situation model", the user constructs a mental model of the spatial surrounding as perceived by the media. This process is affected by both media factors and user characteristics (such as user interests). Afterwards, physical presence would emerge when the user accepts the spatial situation model by confirming a perceptual hypothesis named "medium-as-PERF-hypothesis" (i.e. accepting the assumption that he or she is located in the space). Physical presence is especially important in the design of virtual worlds with gaming elements (such as MMORPGs) where the key aim is in immersing users in a fictional reality space. As for the relationship between physical and social presence, Ijsselstein (2000) argues that while there may be a number of common determinates, physical and social presence could be distinguished meaningfully: one can perceive a high level of physical but a low level social presence in some situations and vice versa in other situations.

Overall, both forms of presence can be argued to be a key component in the study of user interaction in virtual environments. Without presence, the richness of the experience from virtual worlds would be reduced and this might lessen user engagement, satisfaction and any therapeutic effects gained from virtual worlds.

2.6.2 Immersion

Immersion is another theme well discussed in the research of virtual environments. In the context of virtual reality, immersion could be thought of as the state in which the sensory experience of the real world is muted and that of the virtual world is significantly heightened. In the past, immersion was mainly implemented by sensory stimulation, using hardware such as virtual reality gloves. More recently, scholars such as Boellstroff (2008) claim that immersion should be considered in a wider sense then just sensory experience and should include social experience as well. He argued that people feel immersed not only because of the realistic graphics, but also because of the social and cultural realism they experience. Immersion could be linked to presence in the sense that Immersive virtual environments organize sensory information in the way that induces individuals to have a feeling that he/she is present in the environment (Blascovich, 2002).

Bartle (2004) argues that there are four levels of immersion in virtual worlds. Player level immersion, Avatar level immersion, Character level immersion and Persona level immersion. In player level immersion, the user is able to identify with the object they control in the virtual world. As time passes, the user starts to regard those objects as their representative inside the virtual world. This is the Avatar level immersion. As the user becomes more immersed, the user reaches Character level immersion. In this phase, the objects stop being a mere representative and become a representation, an extension of the user's selfhood and personality. Finally, as the user reaches Persona level immersion, the avatar assumes the whole identity of the user; any distinctions of selfhood and personality between the user and the avatar disappear completely.

2.6.3 Selfhood

The concept of selfhood or personhood has also dominated many discussions related to virtual environments and is one of the key concepts in virtual world research. In virtual worlds, users are able to embody identities which are distinct from real life identities. There have even been cases of people having more than one virtual identity and also of multiple people sharing the same virtual identity. Phenomenon such as these have made selfhood a robust area of debate and concern (Boellstorff, 2008). Although it is argued that the anonymity provided by the border between the virtual and the physical selves allows people to create virtual identities distinct from real ones, Boellstorff believes that the selfhood we display in virtual worlds are closer to our real "self", unconstrained by pressures to conform from real life and maybe close to the ideal selfhood which we seek. He argues that it is in the real world where we are forced to role play, to act on a role forced by society. This argument may be supported by the results in one study which found that even though differences between offline and online personalities exist at first, as time spent in virtual worlds increase, the online and offline personalities often diverge till the point of becoming almost identical (Ducheneaut, Wen, Yee, & Wadley, 2009). This divergence might be because self reflection from time spent in virtual worlds allows us to realize our ideal selfhood and adjust our real life selfhood to match it, or as Taylor puts it "*Avatars are not just placeholders for selfhood but are places for self making in its own rights*" (Taylor T. L., 2002).

The ability to have different identities could prove extremely beneficial for older people. Older people could display their true selfhood in the virtual world, their appearance masked by their avatars, and socialize without fear of social stigmatization due to stereotypes (Kizelshteyn, 2008). This could help them gain self confidence and build a network of intergenerational friends.

2.6.4 Social Interaction in Virtual Environments

This section discusses the various studies related to social interaction in 3D virtual environments. Literature in this field is especially important in answering the second and third research questions, on identifying how social interaction in virtual environments could be improved.

Virtual worlds have been designed for a variety of purposes (such as for entertainment, training, education etc) and have various functionalities which users can engage with (object creation, commerce, etc). However, one common factor which enhances their use for each of these purposes is the fact that virtual worlds allow users to carry out social interaction with other users in the virtual environment. For example, learning can be more interactive in a virtual classroom. Users are able to discuss their lessons directly with other students who are represented by avatars. Researchers have also suggested that virtual worlds could play the role of *Third places*, or places which provide spaces for social interaction beyond the realms of home and work, similar to coffee shops or pubs in the physical world (Steinkuehler & Williams, 2006). Partial support for this has been identified in the MMORPG Star Wars

Galaxies (Ducheneaut, Moore, & Nickell, 2004). Similar to *Third places* in the physical world, *Third places* in virtual worlds could be effective in helping bridge social capital and facilitate the expansion of social networks between individuals from different backgrounds (Steinkuehler & Williams, 2006).

A number of studies have been carried out to investigate the social interaction of users in 3D virtual worlds. Harris at el (2009) carried out a longitude study to "*understand individual behaviour within the macro social context of Second Life*". According to their study, as time passed, users were able to increase their social network size and joined more groups. However, as users became more familiar with their environment, they seem to be content with indirect social presence rather than direct social interaction as indicated by the reduced quantity of chat and more time spent in destinations with denser populations. Similar user behaviour has also been reported in MMORPGs such as World of Warcraft (Ducheneaut, Yee, & al, 2006).

More recently, researchers have been interested in studying whether social behaviour (such as social inhibition etc) in the physical world are also present in the virtual world and how they are affected by the virtual environment. In a model proposed by Blascovich (2002), social presence, a factor found to influence many social behaviours exhibited inside virtual environments, is affected by behaviour realism (the degree to which objects behaves as they would in the physical world) and agency ("*the extent to which people perceive others as representations of real persons*"). Blascovich (2002) argues that when social presence in virtual environments passes a certain threshold, influences to social behaviour begin to operate. Social behaviours such as personal space, social inhibition, persuasion and conformity have been argued to be influenced by these factors (see (Harris & al, 2009)). For example, a study showed that users performed more poorly in a speaking task due to the social inhibition effects of an audience of realistic avatars (Blascovich, 2002). Another study showed that virtual audiences which exhibited negative behaviours (such as talking to others, making rude comments, etc) caused more anxiety to both phobic and confident speakers (Slater & Steed, 2002). In addition, studies have also shown that negative behaviours such as stereotypes and prejudice against race (Dotsch & Wigboldus, 2008) and gender (Guadagno, Blascovich, Bailenson, & McCall, 2007) could also be transferred into virtual environments. Users suffering from certain kinds of phobias, such as the fear of public speaking might also exhibit them inside virtual environments as well (Harris & al, 2009).

Unique social conventions also exist in virtual worlds. As the nature of communication varies between virtual worlds (text, audio, avatar mediated etc), social conventions such as how one should initiate a conversation, show commitment to a speaking partner or signal privacy is expressed differently according to the type of virtual world (Becker & Mark, 2002). For instance, users might move their avatars close to another user as a gesture to start a conversation. Understanding these social conventions would be necessary as we attempt to explain some of the social behaviours exhibited by users in virtual worlds.

2.6.5 Motivation of users in Virtual worlds

This section discusses the motivation of users in virtual worlds and the type of activities users carry out inside them. Such knowledge would be beneficial as background context to address the first research question which is to investigate the characteristics, interests and activities of older people who use virtual worlds.

Various models describing the motivation of users in virtual worlds have been proposed. For gaming virtual worlds such as MMORPGs, one study carried out by Yee (2006) had identified three main components which motivated players to use this platform. These components include a social component (chatting with others, forming relationships etc), an achievement component (advancing, levelling up etc) and an immersion component (role-playing, customization etc) (Yee, 2006). For social oriented virtual worlds, a recent study proposed the use of the Uses and Gratifications theory (U&G) to analyse user motivation. This theory argues that a user's decision to use a technology is determined by the functions the technology could serve for its users (Zhou Z. , Jin, Vogel, Xitong, & Chen, 2010). Based on previous U&G research on similar technologies, surveys were conducted with users of Second Life to investigate their motivations for using this technology. The motivations were then grouped into three categories, namely Utilitarian (or termed in another paper as Functional), Hedonic (or termed as Experimental) and Social motivations. The surveys found that 36.41 % of the users use Second Life for utilitarian, 35.7% for Hedonic and 27.89% for Social purposes (Zhou Z. , Jin, Vogel, Xitong, & Chen, 2010) (Zhou Z. , Jin, Vogel, Fang, & Chen, 2011).

What was interesting was that the components from both Yee and Zhou's models were in fact very similar to each other. Both models had social components with similar features (socialization, relationship building etc). Also, the achievement component in Yee's model was also similar to the Utilitarian category. While Yee's achievement component focused on in-game achievements (levelling up, collecting in-game money), Zhou's Utilitarian category also included physical world achievements (being able to learn something new, creating in-world items and selling them for physical world money). In addition, Yee's Immersion component contained similar features as Zhou's Hedonic category, for instance escapism, role playing and exploration of the system. A diagram is shown in Figure 7 to illustrate the similarities between the two models.

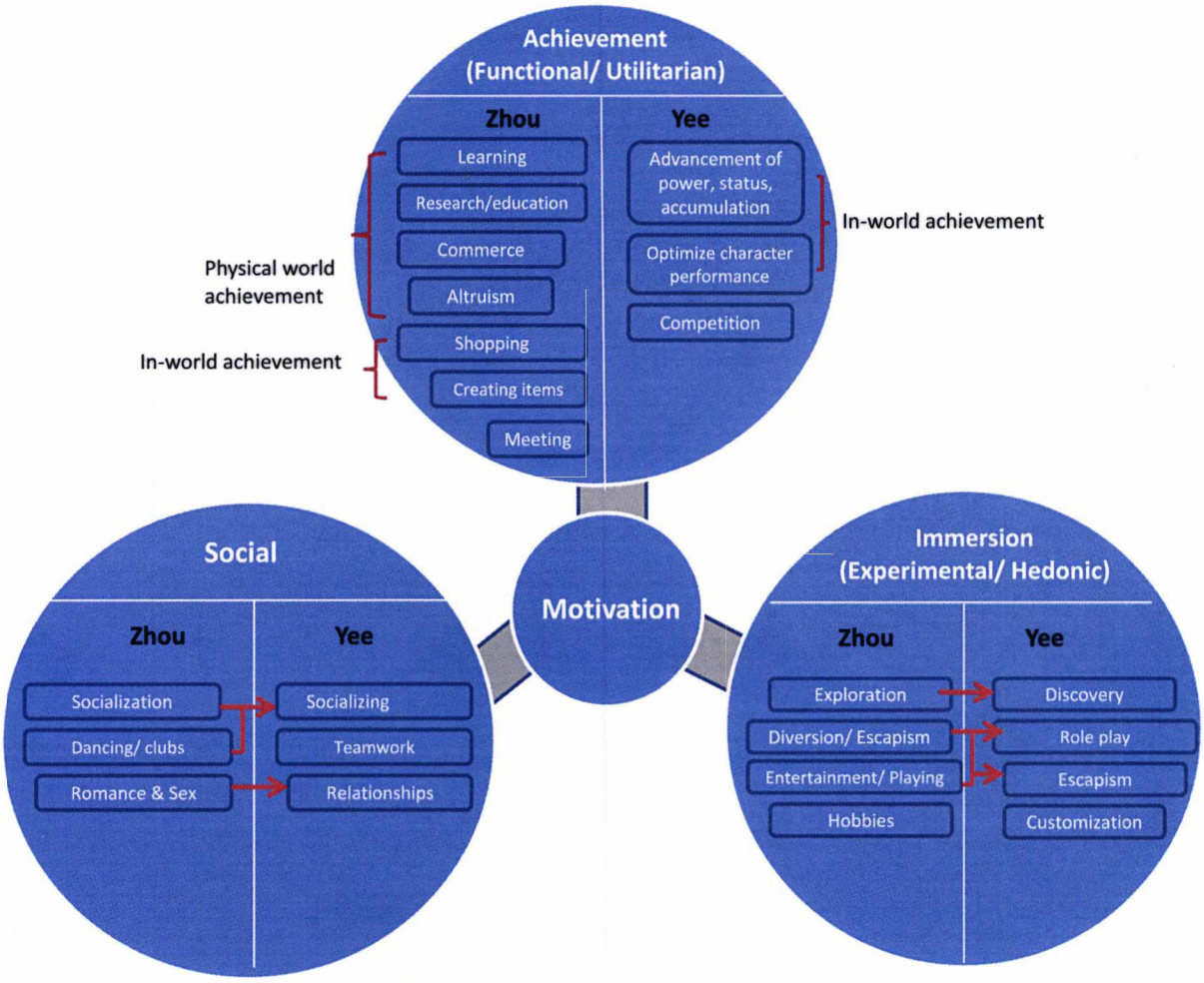


Figure 7 : A Visual illustration of the motivational components from Yee and Zhou's studies

Other studies investigating the reasons users engage with virtual worlds also contain components which are similar to the two models mentioned previously. For instance one study constructed a Technology acceptance model (TAM) to indicate the factors which influence a user's intention of using virtual world technology (Fetscherin & Lattemann, 2008). The model suggests that the value of "community" is the most important determinant of user acceptance in virtual worlds. "Community" they argued, was based mainly on "communication", "cooperation" and "collaboration" (which are mainly social factors based on Yee and Zhou's models). Another study which analyzed user goals using a Means-end chain approach found that purposes such as social relationships and amusement were the main goals of users in virtual worlds (had a high level of centrality in their network). Other goals identified include goals such as knowledge acquisition, content creation and escapism (Jung & Kang, 2010).

Therefore, in studying the interests of older users in virtual worlds, this thesis uses the components proposed by Zhou and Yee as a basis. The components (named based on Yee's model) are Social, Achievement (both In-world and physical world achievements) and Immersion.

2.7 Summary of the literature review

In this chapter, topics related to older people, healthy aging and virtual worlds are discussed, mainly to give definition and define their scope within this thesis. The age criteria set for older people in this study are those who are 55 years or older. The model proposed by Rowe and Kahn was used to define the components of healthy aging. According to this model (Figure 1), healthy aging consists of three components, being absent of disease and disability, maintaining a high level of physical and cognitive functionality and having a continued and active engagement with life (which consists of participation in productive activities and maintaining strong interpersonal relationships). As for virtual worlds, the definition which was adopted was "*Persistent virtual environments which contain representation of real or fictional places that multiple people can inhabit and interact in real time through the use of their avatars*". Several applications of virtual worlds were also identified (information provision, online community and gaming) based on their functionalities.

A number of studies related to how older people engage with online technology were also reviewed. However, little is known about how older people interact with technologies such as virtual worlds. Therefore, two studies were carried out in chapters 3 and 4 to investigate this topic. Afterwards, the literature review then described how technologies with similar functionalities as virtual worlds have been beneficial in supporting older people. Specific examples of the areas in which virtual worlds could potentially support healthy aging were also given. The exploratory study carried out in the chapter 3 would provide evidence to support these examples. Finally, this chapter discussed research on user behaviour in virtual environments focusing on three widely explored concepts; presence, immersion and selfhood. Then, literature related to social interaction and behaviour in virtual worlds were discussed. However, these studies targeted mainly younger users and we do not know whether the findings from these studies would also be applicable to older users as well. Therefore, I carried out two experiment studies in Chapters 6 and 7 to further investigate how these concepts (i.e. presence) affect older user's interaction with virtual worlds. These two studies would also help us further understand the social interaction experience and behaviour of older people in virtual environments.

Chapter 3: Exploring the potential of virtual worlds in supporting healthy aging

In the previous chapter, a number of studies examining how older people engage with computer technology and how those technologies could be beneficial in supporting older people were discussed (sections 2.4 and 2.5). Afterwards, the chapter proposes how virtual worlds with similar functionalities as those technologies could also have potential to support healthy aging (sections 2.5.4 and 2.5.5). One recent survey carried out with users in Second Life found that almost 6% of users were those who are aged 55 and above (The Second life Survey, 2007), indicating that there are older users who actively use virtual worlds. However, little is known about these users and how they use virtual worlds. The studies carried out to investigate these factors mostly focus on younger users (section 2.6).

To provide an overview of the characteristics, interests and activity patterns of older virtual world users, I carried out an exploratory study where such users were interviewed about their experiences with virtual worlds. The findings were then analyzed in relation to the definition of healthy aging proposed earlier in section 2.2. This was done to determine which of the areas suggested to be beneficial in supporting healthy aging coincide with how older people actually use virtual worlds.

The aims of this study were to:

1) investigate the potential of virtual worlds in supporting healthy aging based on the characteristics, activities and the nature of social engagement of older users in virtual worlds.

2) Identify key issues in older users' characteristics, interests and activities

3) Investigate key issues in older users' social engagement in virtual worlds.

The results from this study were published as an article at the Behaviour and information Technology journal (Siriaraya, Ang, & Bobrowicz, in press).

3.1 Selection of Virtual World

The first step of this exploratory study was to identify appropriate virtual worlds which contain older users. Several prominent virtual worlds featured on de Freitas's serious virtual world report were investigated (Freitas, 2008). Older users were identified either from i) using the user search function provided by the virtual world service ii) posting in community boards related to the virtual worlds (such as the Second Life forum[13], World of Warcraft[14] forum) or iii) browsing through user groups with themes related to older people from the

[13] http://community.secondlife.com/t5/Forums/ct-p/Forums
[14] http://us.battle.net/wow/en/forum/

service provider. Overall, a number of virtual worlds, namely Utherverse[15], Omnidate[16], IMVU and Second life were found to possess significant communities of older people.

Based on this preliminary investigation, I decided to carry out the study with older users from two virtual worlds, IMVU[17] and Second Life[18] (See Figure 8). These virtual worlds were selected because there were a large number of active older users. In Second Life, there were various user groups catering to older users (such as Swinging Seniors, SL seniors, Geezers!, Seniors of SL). In IMVU, an online search of age-verified users suggested a sufficient number of older people were present for meaningful analysis. Utherverse and Omnidate were not selected due to the overemphasis of the virtual world on a specific aspect of interaction (virtual dating and sex). Both IMVU and Second Life subscribed to the definition of virtual worlds proposed in section 2.3.

Figure 8: Screenshots of the two virtual worlds used in this pilot study. On the left hand side is IMVU and on the right hand side is Second Life

IMVU is a social networking platform augmented by a 3D instant messaging service (IMVU, 2011) (Figure 8). This platform is interesting in the sense that it contains both a 3D virtual world and a social networking element. As a 3D virtual world, this platform allows users to carry out a number of activities such as shopping for clothes or objects to decorate their rooms. Users are also able to socialize with others either by visiting a public chat space (which could take the form of a beach or club house etc) or a private chat space (usually the users' private rooms which they could customize). Users can also use their avatars to interact with the environment (such as sitting on a chair etc) and with other user's avatar (such as dancing with each other or waving to each other). Communication is mainly carried out through text base chatting which would be shown as "speech bubbles" floating above the avatar. IMVU also allow users to create a profile page. These profiles are similar to user profiles of online social network sites such Facebook or Myspace.

Second Life is a virtual world which has many similar features as IMVU. Second life also contains features which allow for user generated content and a commerce system where users can sell objects in a virtual currency which is exchangeable to physical world money

[15] http://www.utherverse.com/
[16] http://www.omnidate.com/
[17] http://www.imvu.com/
[18] http://secondlife.com/

(Sivan, 2008). It is also host to a large number of environments from replicas of physical world cities to environments created from science fiction or fantasy literature. Second life is also home to a large community of users and has frequently been featured in academic studies from many domains (such as (Freitas, 2008), (Ford, 2001), (Harris & al, 2009)). A number of government organizations and corporations in the physical world have also established a presence in this virtual world (Mollick & Edery, 2008).

3.2 Exploratory Study method

Semi-structured interviews were used to investigate the characteristics, interests and interaction patterns of older people in these two virtual worlds. A total of 15 older users from these two virtual worlds were interviewed. Eight participants were recruited from IMVU and seven came from Second Life. Participants were recruited through opportunistic sampling, due to the small and specific nature of the intended target user group. In IMVU, the built-in search function was used to identify potential participants. To ensure the integrity of the sample, only age verified users were recruited. Users can be age verified by providing an official document such as a copy of their passport or driver's license to the IMVU service provider. In Second Life, the owners of several established user groups catering to older users were contacted and asked to recommend participants to this study. The criteria used in the recruitment was that potential participants had to be older than 55 years and must be current users who had used virtual worlds for at least 3 months. The 3 month criterion was selected due to the thought that users who had used virtual worlds for at least this duration would be familiar enough with the various functionalities and avenues for interaction offered by the virtual worlds. These users would also have sufficient experience from engaging with the various activities available in the virtual worlds. Therefore, such users would be knowledgeable enough to provide meaningful responses to the interview questions.

E-mails were then sent to these potential participants, explaining the purpose of the study and requesting them to take part. Participants were interviewed online, within the virtual world. In IMVU, participants were invited to a private room and were interviewed using text based chat. In Second Life, a meeting was arranged with participants in a virtual public space and interviews were conducted through a private text based chat channel. Each Participant was interviewed for approximately 1.5-2 hrs. Even though voice communication was available in these virtual worlds, participants were interviewed using text-based chatting. This was because most participants did not have the necessary hardware (headset, microphone etc.) required for VOIP (Voice over-IP) communication and because most of them were more familiar with this method of communication in the virtual world.

3.2.1 Interview structure

The interviews focused on four dimensions: i) generic questions about the users themselves, ii) issues related to the use of virtual worlds for social interaction, iii) the types of activities users carried out and iv) any benefits they perceived from using virtual worlds. The interview

questions could be found in Appendix B. Specifically, the interviews covered the following topics:

1. ***Users:*** the demographics, user characteristics, interests and usage patterns of older users in virtual worlds. Open questions such as "Please tell me more about yourself" and "What would you say is the main reason you are using virtual worlds?" were asked.

2. ***Social engagement:*** the nature of the relationships with other users and issues perceived by older people to be important in communication and social interaction in the virtual world. Open questions such as "What kind of activities do you do with your friends in virtual worlds?" and "How do you feel about your social experience in virtual worlds?" were asked.

3. ***In-world Activities:*** The activities older people conduct in virtual worlds. Open ended questions such as "Please describe the activities you usually do in virtual worlds" were asked.

4. ***Perceived Benefits:*** The benefits older people perceive from using virtual worlds. Questions include, "Do you feel that using virtual worlds have any benefits to you personally? Can you give an example?" were asked.

3.2.2 Data analysis

Thematic analysis was used to iteratively analyse the data (Braun & Clarke, 2006). This method allows us to generate an extensive overview of the topics related to the interests, characteristics and activities of older virtual world users. Other research methods such as grounded-theory analysis also exists which allows us to construct a theoretical understanding of the data and to analyze the relationships between the topics. Such methods were not used in the analysis, as the key aim of this study focuses on identifying a wide range of themes to lay the foundation for in-depth exploration in future studies rather than to construct a theoretical model. These factors have been analyzed in more detail using other research methods in chapters 6 and 7 (such as the examination of how user characteristics influence user experience).

The interview scripts were loaded into the software ATLAST.ti 6[19] which was used to facilitate the analysis process. First, the transcripts were read through in order to gain an understanding of the overall context. Emerging patterns were then extracted from each transcript and labelled with codes (Joffe & Yardley, 2004). Similar codes were grouped together into higher level codes and themes were created from the recurring codes as part of the thematic analysis process. The themes and codes were then reviewed and refined until saturation had been achieved. Afterwards, the themes were further reviewed by two

[19] http://www.atlasti.com/

independent coders. This was done by presenting the themes to the coders and asking them to critically review the themes until both coders agreed on the final themes.

A number of themes were identified in relation to the characteristics of the users, the nature of their social interaction and the type of activities they carried out. The themes were then analyzed and interpreted in relation to the definition of healthy aging as was proposed in section 2.2, namely Rowe and Kahn's model of healthy aging (Rowe & Kahn, 1997). This was done to provide an analysis into the potential value of virtual worlds in supporting healthy aging, mainly to provide directions for addressing the forth research question.

3.2.3 Ethical considerations

As this study deals with older adults, various steps were taken to ensure the confidentiality and anonymity of the participants in the interviews and the overall ethicality of this study. First, the study was reviewed and approved by the University of Kent's ethics review board. Participation was voluntary and an online consent form was used to obtain consent from the participants. Names were replaced with pseudonyms to protect the virtual and real identity of the participants. In addition, the interviews inside the virtual world were conducted in a private space or through private communication channels to ensure confidentiality.

3.3 Study Results

A total of 15 older users participated in the interviews. The average age of the participants is 58.73 years, the oldest being 65 years old (SD=3.515). Although it would have been extremely interesting to also examine participants of a more senior age range as well, such participants were not available to interview in virtual worlds as at present older people who use virtual worlds remain a small and specific sample group. Nevertheless, as discussed in section 2.1.1, page 21, such participants are relevant to this study as in the future, they would likely be the main bulk of those who continue to use and benefit from virtual worlds as they grow older.

The results are presented as follows: First, the general characteristics and demographics of older people who use virtual worlds are presented. Then, the themes identified from analyzing the characteristics, social engagement and activities of older people in virtual worlds are presented in relation to Rowe and Kahn's model of healthy aging.

3.3.1 User Demographics and characteristics

Table 3 summarizes the demographics of the older people who participated in the study and their previous experience with computer technology.

Demographic variable		Number of participants
Sex	Male	7
	Female	8
Marriage status	Married	11
	Divorced	3
	Widowed	1
Frequency of usage	Daily	6
	Almost daily	7
	Occasionally (more than twice a week)	2
Technology usage	E-mail	15
	Social network sites	10
	Messenger programs/ online chat	10
	Video games	7

Table 3: A summary of the key characteristics of our participants in the pilot study

As shown in Table 3, it is clear that a large proportion of older people who used virtual worlds were relatively tech-savvy. In the sample, more than two thirds of older people were social network or online chat users and nearly half of them had experience with video games. This was considerably different from the general population of older internet users where only 43% of those aged 56-64 use social network sites and only 30% use instant messaging programs (Pew Research Center, 2010a). The familiarity with technology of most older people in the sample did not come as a surprise, as interaction with virtual worlds usually requires a considerable level of familiarity with computer technology. For instance, it is generally difficult to perform actions in a 3D space with the constraints from current input mechanisms (mouse, keyboard etc) (Pfeil, Ang, & Zaphiris, 2009). What was more interesting was that they not only were able to overcome this usability barrier, but were also able to learn to access the advance functionalities of virtual worlds (such as using graphical programs to create virtual items for their avatars). More about this is explained in section 3.3.2.2.3. Apart from this, a considerable number of participants reported being in some way limited in mobility (7 out of 15). This includes those who became physically disabled from an accident, from age related diseases, were suffering from a temporarily disability while waiting to recover from a medical operation and even those who cited that they need to rely on friends or kinship for transportation. More about this and the implications towards healthy aging is explained in section 3.3.2.4.2.

In one of the questions, participants were asked to discuss the main reason they used virtual worlds. The motivations reported were then grouped in relation to the components of user motivation in virtual worlds constructed based on Zhou and Yee's study (2010) (see section 2.6.5). 3 older users (20%) reported Achievement (altruism, shopping, promote own business etc), 3 (20%) reported Immersion (escapism, entertainment etc) and 9 (60%) reported socialization (Socializing, keeping in touch, romance, etc) purposes as their main reason for using virtual worlds. Compared to the results published by Zhou et al (2010) (social (27.89%), Hedonic (comparable to Immersion) (35.7%) and Utilitarian (comparable to achievement) (36.41%)), it would seem that older people are mainly interested in using virtual worlds for

social interaction. This result should be interpreted with caution however due to the low number of samples in this study.

3.3.2 Potential value of virtual worlds in supporting healthy aging

The themes identified from analyzing the characteristics, social engagement and activities of older people in virtual worlds were then grouped together in accordance with the components of healthy aging they were related to. Four dimensions of how virtual worlds could be beneficial in supporting healthy aging were identified. These dimensions include the potential value of virtual worlds in empowering older people to manage their disease and disabilities (in relation to the "low probability of disease and disability" component), facilitating social engagement, facilitating participation in productive activities (both in relation to the "active engagement with life" component) and providing mental stimulation (in relation to the "high physical and cognitive functioning" component). Figure 9 provides a graphical summary.

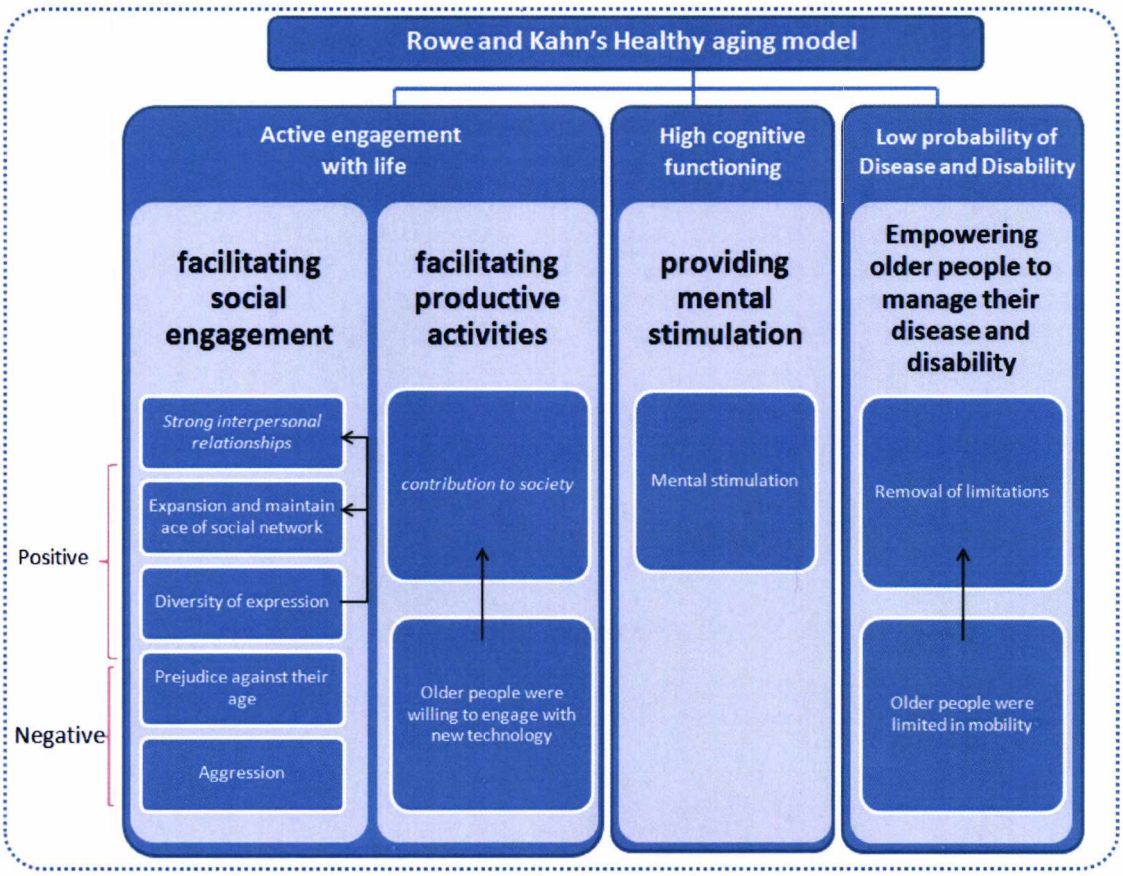


Figure 9: A graphical summary showing the relationships between the themes and dimensions identified from this study and the components of healthy aging

3.3.2.1 Potential value of virtual worlds in facilitating social engagement

The first dimension identified from the analysis was related to the potential value of virtual worlds in facilitating social engagement. The maintenance of interpersonal relationships is

considered to be a major element of *continued active engagement with life*, which in turn is an important component for the healthy aging of older people.

3.3.2.1.1 The value of virtual worlds in facilitating deep interpersonal relationships

From the interviews, older people reported being able to form *deep interpersonal relationships* in virtual worlds. They reported forming friendships transferable to offline settings and developing romantic relationships in virtual worlds.

> *"I have also started friendships in here (in the virtual world) with people in other countries....We spend time together [in the virtual world], talk about problems, play games like cards, billards, chess. Some of these friends are people I consider to be very close. They know a lot about me and my situations and I know a lot about them" (Participant H, male, 57)*

Other participants also mentioned developing friendships in virtual worlds which have lasted for long durations. Some of these friendships even transferred to offline friendships. This was reported by nine of the participants.

> *"This person who I met in the virtual world], she and I are close. 5 years we have known each other. She lives in [a foreign country]. I would not have met her [outside the virtual world]. We talk everyday about work, her children, family and everything... it is so nice, my social life is here, my friends are here." (Participant O, female, 62)*

> *"I met a girl here [in the virtual world] almost three years ago,... we became good friends....then [we] started talking on the phone .... I went to [a US city] last year to meet her... stayed with her and her family for almost two weeks." (Participant J, A female participant, 57)*

As such forms of deep interpersonal relationships have been reported in virtual worlds for users of other age groups (Boellstorff, 2008), it is not surprising to see older people benefiting from virtual worlds in similar ways. What was particularly interesting was some of the reports on how virtual worlds helped facilitate the establishment of relationships for older people. For instance, older people reported that avatar mediated communication helped in the establishment of interpersonal relationships with users of younger age groups.

> *"Some of the friends I've made are in their 20's, a couple of young girls, we have fun at the water park....they were open about my age and said it didn't matter on here how old I was and we just played like a bunch of kids" (Participant B, A female participant, 62)*

Interaction through avatars not only helped reduce the physical barriers required to participate in social activities, but also anonymized the physical world status of older users. This allowed older people to blend into communities of younger users and participate in social activities together with them.

"You are ageless here... here I can be with similar ages and keep up with clothes and fashion and what they like and dislike ... no one knows what age I am [and] no one knows in a club if I am another 18 year old dancing alongside... so I can blend and just listen to the talk .... I couldn't do that in Real life" (Participant O, female, 62)

This instance shows how virtual worlds have acted as a bridge in the social interaction between them and younger users due to the mediation of interactions through avatars.

Another form of deep interpersonal relationship which older people reported being able to develop inside virtual worlds were satisfying romantic relationships. This was reported by eight of the participants in the interviews. Participants often expressed that compared to other communication tools such as text messaging programs and e-mail, virtual worlds provided more diverse methods of interaction which made it easier to establish and maintain romantic relationships. According to the participants, virtual worlds not only allowed them to communicate with their partners in a similar manner to other online chat programs, but also allowed them to participate in immersive social and sometimes intimate activities together. The ability to visually express romantic emotions (cuddling, kissing, etc) as animations in the virtual worlds was also found to be very satisfying.

"I met [him] at [a] romantic beach... and we start talking, you know say hi...then we sat down around a campfire and we found we had a lot of things in our mind that connected...then maybe the next day we meet and dance or go to an exciting place.... and we like just decide we get along and we date and dance.... [we] like being with each other,[so] we decide to be boyfriend and girlfriend,...and a relationship has started." (Participant K, female, 62)

3.3.2.1.2 The values of virtual worlds in helping older people expand and maintain their social networks

Apart from helping facilitate the development of deep interpersonal relationships, participants also reported that virtual worlds helped them *expand and maintain their social networks*. Twelve of the participants emphasized on how virtual worlds allowed them to meet new people and keep in touch with existing friends.

"I have a few friends I made online back in the 90s, we have maintained our relationships all these years. They have come to [the virtual world], we are having so much fun.... I love making new friends here, it's my main source of friends now" (Participant C, A female participant, 61)

"One thing great about virtual worlds, you have a large pool of friends.... as you get married and have kids....you lose contact with almost everyone, here in the virtual worlds, you have all those friends again, to talk [and] to laugh with.... here you are free to socialize.... the ability to meet people here is endless" (Participant N, A male participant, 55)

Literature has pointed out how such activities are an important aspect of life in social oriented virtual worlds and how virtual world inhabitants spend a considerable amount of time and effort on such activities (Boellstorff, 2008). This was also true for participants in the

interviews, as nine of our participants reported social interaction as the main reason for using virtual worlds.

As similar uses of other computer mediated communication (CMC) tools by older people have been well reported in literature (Blit-Cohen & Litwin, 2004), it could be argued that one use of virtual worlds by older people is as a form of CMC. One reason why older people use virtual worlds might be similar to why they use email and other online communication tools, which is to reduce loneliness or to socially interact with friends (Karavidas, Lim, & Katsikas, 2005). However, participants indicated that virtual worlds have provided a more satisfying social experience due to the ***diverse channels of expression*** available. When compared to other CMC tools, participants felt that interactive avatars allowed them to better express themselves and this increased the richness of their social interaction. This was cited by four of the participants.

> *"[When] talking to people, nothing compares to virtual worlds, as far as animations and intimate interactions, you can feel people, touch them, feel their emotions, [you can] hold their hand and feel it" (Participant N, male, 55)*

Participants also reported being engaged with the wide range of activities available in virtual worlds. While social interaction in other computer mediated communication tools is limited to either just text based or voice based communication, virtual worlds provide a more immersive social experience, allowing older users to interact with friends through a number of social activities.

> *"For older people who are house bound or bed confined or crippled [Virtual worlds] are perfect.....they can interact with family and friends on a regular basis [and] not just to keep in touch, but to go to an amusement park and ride a rollercoaster, or go skiing on a snowy mountain, or do anything [they want to] (Participant F , male , 62)"*

> *"I like [virtual worlds] because it's like being there...Facebook is too restricted and Skype is more for a personal thing, virtual worlds takes it from just printed type to a more fun and interesting experience....here I can have and do what I want"*
> *(Participant M, A male participant, 55)*

Another reason why participants use virtual worlds for CMC was because they have limited opportunities to meet new people and expand their social network physically due to mobility restrictions. The advantage of virtual worlds in providing an opportunity for older people to meet and carry out social activities with other people, often from all around the world, without having to physically travel was frequently mentioned in the interviews.

> *"I can visit my friends in different parts of the world here easily....best friends here in ,NY, Japan, Canada, Indiana, Virginia, Australia, UK.... it can be something to keep a person from being bored because they are stuck at home" (Participant J, female, 57)*

This use of virtual worlds as a form of CMC would have many benefits to the health of older people. The network of friends gained from virtual worlds could offer the same benefits as

companionship networks in online communities, helping older people feel more integrated in society (Wright, 2000).

3.3.2.1.3 The barriers of social engagement in virtual world for older people

It is also worth mentioning that two themes emerged as barriers to the social engagement of older people in virtual worlds. In the first theme, *forms of aggression* such as rudeness, harassment and violent behaviour acted as deterrents to the development of relationships and to social interaction for the participants. These forms of aggressions were in many ways similar to the acts of griefing which are commonplace in massively multiplayer online games (Foo & Koivisto, 2004) and social-oriented virtual worlds (Boellstorff, 2008). These forms of aggressions have been a frequent source of complaint by many of the participants during the discussions. However, this might not reflect the frequency of such events occurring in virtual worlds, as some of the participants who reported about griefing in the interviews also noted that they only encountered a few rude people and most were helpful and pleasant.

While previous research have often cited how stereotypes and prejudice against race (Dotsch & Wigboldus, 2008) and gender (Guadagno, Blascovich, Bailenson, & McCall, 2007) could be transferred to the virtual domain, in the second theme, participants reported a form of prejudice against their age existing in the virtual world. Five of the participants told of how sometimes younger people seem to consider them as "unwanted presence" when they found out about their real age and often dropped out from the chat immediately afterwards.

> *"There have been a couple of young people who asked what I was doing on here. I told them old people like to talk and make friends too. He left the chat immediately." (Participant B, female, 62)*

> *"Some people have found out my age and left right away" (Participant D, A female participant, 55)*

Despite this, participants seem to hold positive attitudes even after encountering such incidents and reported that such incidents would not discourage them from using virtual worlds as a tool to socialize.

3.3.2.2 Potential value of virtual worlds in facilitating productive activities

Participation in productive activities has been argued to help provide continued engagement with life for older people, which is an important component of healthy aging. Activities such as paid or unpaid work which provide contribution to society (such as volunteer work or informal help giving) are considered as being productive (Rowe & Kahn, 1997).

3.3.2.2.1 The potential value of virtual worlds in helping older people contribute to society

Virtual worlds could be used as a platform to allow older people to contribute to society more easily. In the interviews, there were a large number of *altruistic activities* which were identified. For example, one participant created and managed a virtual ballroom which was open to public users for free. Another participant reported regularly visiting locations for new users and helping them become more familiar with their new environment by giving technical advice and guidance.

> *"I go out to the newbie [new users] landing places and see who might be there that needs help... [I] instruct what I can to make their experience here easier or more fun... sometimes I might take them to places, but mostly I teach them how to find things"*
> *(Participant J, A female participant, 57)*

Other participants also reported using the experience from their previous careers to volunteer to teach others through the virtual world. For example, a participant who recently retired from labour delivery offered to teach classes in child birth while another who had experience as a dog trainer taught other users about dog training through a virtual park he owned and built.

> *"I joined a group here, the maternity clinic. I am going to be teaching childbirth classes there...I am putting my lesson plan together... I am really looking forward to taking my knowledge, especially since I just retired, [and] to extend it to the online community"*
> *(Participant C , A female participant, 61)*

In addition, participants also mentioned sometimes acting as a kind of mentor or advisor to younger users, giving advice or providing social support to their younger peers.

> *"sometimes I just end up giving grandmotherly advice.....That brings out the grandmother in me...I'd say they start out complaining about something and I redirect things a bit give them options"(Participant B, female 62)*

> *"He was having girl problems.... And was really hurting.... I was able to be the substitute mom he needed" (Participant C, female 61)*

3.3.2.2.2 The potential value of virtual worlds in facilitating paid work

As argued in section 2.5.5.6, virtual worlds have the potential to provide older people with opportunities for paid work. Although none of the participants directly reported employment or earning money as their main purpose of using virtual worlds, there were examples of participants using virtual worlds to facilitate paid work. One participant who reported being a

professional artist after retirement used virtual worlds to promote his artwork. Another had reported receiving a modest income from selling items he created in the virtual world.

3.3.2.2.3 Willingness to learn about and engage with new technology

Most of the productive activities conducted by older people in the interviews usually require a familiarity with the advance features of virtual worlds (such as developing the materials necessary for teaching in classes etc). Participants did not seem to have much trouble using virtual worlds for such tasks, despite the high learning curve usually required. Seven of those interviewed had already built or animated a number of objects in the virtual world. Participants seem to do such activities mainly for the sheer joy of being able to create virtual items. It was common during the interviews for participants to point out proudly to some of the objects that they had built in the rooms which they were being interviewed at or to describe with a sense of accomplishment how they were able to create and share certain objects with their friends. To create these objects, participants were willing to learn more about advance computer concepts such as 3D modelling and programming.

> *"I also built some things that were unique. Like a water globe type thing with a box on top that spun with my photo in it for my boyfriend.... I took a scripting class and would like to do more. I did really well too. Made a doormat talk when you stepped on it, simple stuff". (Participant K, A female participant, 62)*

Although eleven of the participants reported having considerable prior experience in using computers, three had almost no prior experience and started learning about computers and technology when they were using virtual worlds.

> *"I had never turned on the computer before [I used virtual worlds]....plus I was uneducated. [I have] never been to school even elementary school... I began learning so I can build things...I had to learn about textures and more about the computer languages... I became interested in other concepts because of my needing to get these things ready in the virtual worlds. I was forced to start reading about them on the web." (Participant L ,male , 58)*

Overall, the opportunity to pariticpate in productive activities was extremelly beneficial for participants as virtual worlds allow them to contribute to society despite the limitations of their physical abilities. Productive activities have been found to improve the well-being of older people (Morrow-Howell & al, 2003) and are considered to contribute to active aging which results in a higher quality of life (Bowling A. , 2008).

3.3.2.3 Potential value of virtual worlds in providing mental stimulation

Maintaining a high cognitive function is also an important component of healthy aging. One benefit ascribed to virtual worlds during the interviews was that virtual worlds provided a form of *mental stimulation*. Virtual worlds not only helped keep older users mentally active, but also provided them with an avenue to learn new skills and acquire new knowledge.

"I met [a guy] in a club [in the virtual world] where everyone was bilingual except me....I said I speak a little French.... he came to chat at a later date.... threw some phrases at me. I figured them out for the most part... now he comes about once a week for my French lesson...he is very nice" (Participant D, female, 55)

Six of the older users that were interviewed also mentioned that being in the virtual world by itself is a form of mental stimulation.

"Doing anything at all here will keep you mentally active... from hunting through inventory for clothes, or organization process....Building things, talking to people, exploring" (Participant J, female, 57)

Although virtual worlds presented various opportunities for learning such as classes and virtual museums, most participants expressed only minimal interest in visiting such places or joining such activities. Even though three of the participants interviewed reported participating in these activities, they seem to see them as opportunities for social engagement rather than learning.

3.3.2.4 Potential value of virtual worlds in helping empower older people to manage their disease and disability

Another component for healthy aging suggested by Rowe and Kahn's model is the avoidance of disease and disability. As such, technology which reduces the risks of diseases and disabilities for older people could be considered beneficial in supporting healthy aging. The interviews identified several possible implementations of virtual worlds in this dimension.

3.3.2.4.1 The potential value of virtual worlds in helping reduce the risk of diseases for older people

As shown in section 2.5.5.1 previous studies have pointed out that virtual worlds had the potential to be beneficial in providing health information. Although older users in the interviews had sometimes mentioned virtual worlds as being beneficial to their health, they had not specifically stated that they had used virtual worlds to receive health information. One reason could be because older people perceive virtual worlds more as tools for leisure and social interaction. Therefore, they might turn to other tools such as the Internet when they wish to acquire serious information related to health.

3.3.2.4.2 The potential value of virtual worlds in mitigating the effects of disabilities

Although virtual worlds might have no direct benefits in reducing the risk of disability for older people, the interviews did indicate that virtual worlds might help mitigate the effect of the disabilities on their lives instead. This was supported by one of the themes where six participants reported that virtual worlds helped *remove the limitations of their disabilities and age*. Older people reported how they were able to once again enjoy the experiences of "outdoor activities" such as dancing and swimming. Those who were limited in mobility also reported how virtual worlds helped remove the limitations of their disabilities, allowing them to carry out activities and socialize without the need for physical travel.

"[Virtual worlds] enable [older people] to do the things they can no longer do. Fun things.... it is a joy to be able to swim, jump, run, ride animals, and fall off a waterfall, and swing like tarzan through the jungle.... and I can do all of those things in my rooms" (Participant B, female , 62)

"In here, we have visited beach resorts, gone skiing, ridden horseback, had picnics and visited a variety of dance venues we would not normally participate in.... I wouldn't have the time [and] wouldn't be able to physically do [such activities] .....you don't see many people in their 50's enjoying a night of break dancing [in the physical world]
(Participant H , A male participant, 57)

According to our participants, such removal of limitations was made possible through the embodiment of user interaction through avatars. Even though virtual worlds did not directly help improve the physical abilities of older people, they helped reduce the physical effort required to carry out activities and social interactions. Inside the virtual worlds, participants were able to enjoy those activities regardless of their physical abilities.

Due to such potential benefits, it might not be a surprise that a considerable number of older people using virtual worlds in the interviews were in some way *limited in mobility*. Some of these users even reported that their disability was what motivated them to start using the virtual worlds in the first place.

"I had a brain injury, I came to [the virtual world] because I was in a prolong coma, after a couple years of rehabilitation I decided to try [the virtual world] out to see what it was about.... The doctors told her how normal [virtual worlds] had made me....my brain injury doesn't affect me...[Virtual worlds] has given me self confidence "
(Participant L , male, 58)

"I'm pretty much confined to the wheelchair, I can do only a little shopping at a time. And though I used to dance 3 times a week, I can only dance [in the virtual world] now"
(Participant B, A female participant, 62)

In a sense, much of the benefits of virtual worlds in this dimension could be similar to those identified for physically disabled users (such as presenting older users with a feeling of empowerment (Ford, 2001), (see section 2.5.5.2)) as there are many similarities in the social and physical constraints shared by home bounded older people and physically disabled people.

3.4 Conclusion and Chapter implications

In this exploratory study, semi-structured interviews were conducted with fifteen older users from two virtual worlds, IMVU and Second Life to identify the characteristics, interests and activities of older virtual world users and their social engagement in virtual worlds. These themes were analyzed and presented in relation to Rowe and Kahn's model of healthy aging.

Four areas where virtual worlds could be beneficial in supporting healthy aging were discussed. Virtual worlds could help mitigate the effects of age related diseases and disabilities (by providing an avenue for users to carry out activities regardless of their physical limitations), facilitate social engagement (by allowing users to develop both in-depth relationships and expand their social networks), provide opportunities for carrying out productive activities (such as activities which allow older people to contribute to society) and could be beneficial in providing mental stimulation (provide an avenue for older people to learn new skills and knowledge).

Another objective in this study was to provide an overview into the characteristics, interests and activities of older people in virtual worlds. The results were used to address the first research question. Analyzing the users' characteristics showed a number of interesting trends. First, older users were those who were already quite familiar with computer technology and were willing to expand their knowledge in this domain to access the advance functionalities of virtual worlds. Apart from this, older people who participated in virtual worlds seem to be keen to carry out activities of an altruistic nature, particularly those which made productive contributions to other users. Another interesting trend was that a number of these users suffered from a limitation in their mobility. As interaction in virtual worlds is mediated by avatars, this removes the limitations of age and physical ability. Therefore, it is not surprising why a considerable number of users who are limited in these aspects seek to use virtual worlds.

In regards to their social engagement, older people were able to develop both deep interpersonal relationships (long lasting friends, romantic partners) and use virtual worlds to expand and maintain their social networks. However, the results also showed a number of barriers to the social experience of older users, including incidences of prejudice against their age and forms of online aggression.

In the next chapter, the results from a quantitative study carried out to investigate the demographics, usage patterns and activities of older virtual world users are presented. While this chapter offers a rich descriptive explanation into how older people use virtual worlds, the next chapter would provide empirical data to enhance the findings in this study. The results from both studies were used to address the first research question.

Chapter 4: The analysis of user profiles of older Virtual world users

The previous chapter described a qualitative interview study that provided an overview of the characteristics, interests and activities of older virtual world users and the potential benefits of virtual worlds in supporting healthy aging. In this chapter, the results from a quantitative study are presented to provide empirical data to strengthen our understanding of how older people use virtual worlds. The results from both studies are used to address the first research question.

Overall, the analysis of user profiles in this study focused on three main areas. The first was the demographics and characteristics of older people who use virtual worlds. The second was their activity patterns (more specifically, their social network and online gift giving behaviour). The final area focused on the interests of older people based on the type of user groups they participated in. The results were analyzed in comparison to younger users. This was done to help highlight the unique interaction and behaviour patterns of older users in virtual worlds. Studies of a similar nature have also adopted such methods in studying the interaction of older people in technologies such as social networking services (Pfeil, Arjan, & Zaphiris, 2009) and usenet news groups (Zaphiris & Sarwar, 2006) .

The results from this study have also been published as an article in the Computers in Human behaviour Journal (Siriaraya & Ang, 2012a).

4.1 Method

To identify the characteristics, interests and activity patterns of older virtual world users, online user profiles from IMVU were collected and analyzed. IMVU is a combination of both a 3D virtual world and a social network service (please see section 3.1 for more information). Apart from being able to interact with others in a 3D virtual environment, users are able to create a profile page for their avatars. These profiles are similar to those found on other social networking services such as Facebook, containing information about the characteristics of the user (for instance, age, gender, marriage status etc) and their in-world activities (such as the number of gifts exchanged or type of groups joined). The main reason this virtual world was selected was because of the rich information about the users which were made publically available from the profile pages. More importantly, this virtual world contains a substantial number of active older users.

4.1.1 Data collection

An automated web crawler was developed using the Perl programming language to collect information from the profiles. The web crawler first used the IMVU search page to identify the profiles of older virtual world users (aged 55 or above). Information from the profiles identified from the search (a total of 3100 profiles) was collected. An XML parser library,

HTML::TreeBuilder[20] was used to examine the HTML page. The parser used the HTML tags in the page to identify the relevant information (using the look_down method). The information was then extracted and stored in a file. If no information was available, "NO_INFO" would be added instead. The file was then later imported into SPSS for statistical analysis. Afterwards, a similar number of profiles of younger users (aged 18-22) were also collected to be used as a comparison group. Profiles of users in this age range were selected as such users tended to be those who are well engaged with many forms of online technologies and represent the typical user of virtual worlds. Profiles of younger users were randomly selected from the search page and the same process which was used to collect data from older users was applied. The average age of the older people in the sample was 61.15 years (SD=5.02) and the average age of younger people in the sample was 19.3 (S.D=1.04).

The data was further processed by removing non-English profiles and profiles with no basic information (usually profile pages heavily customized by users that display no information useful for our analysis). As with all other research studies examining the characteristics of users from self reported profiles in online social networks (such as (Pfeil, Arjan, & Zaphiris, 2009), (Thelwall, 2008), (Hinduja & Patchin, 2008)), one limitation was the risk of including fake profiles in the analysis. Therefore, steps were taken to minimize this affect. First, the investigation of older profiles were limited to those aged lower than 80 as studies have found that online profiles of users aged beyond 80 (Hinduja & Patchin, 2008) or 90 (Thelwall, 2008) tended to be younger users misrepresenting their age. Profiles which were newer than a day were also removed, as such profiles tended to be "test profiles" which users created and used only once. Afterwards, each of the remaining profiles were manually inspected and 72 user profile of older users which seems to be profiles of younger users who misreported their age (for instance, their profile descriptions contain texts such as "Sorry, my age is wrong, I'm not really in my 60's ....") were removed.

After filtering out those profiles, a total of 2445 profiles of younger people and 2551 profiles of older people remained and were used in the analysis. Table 4 provides a brief description of the types of information that were collected for analysis in this study.

[20] http://search.cpan.org/~cjm/HTML-Tree-5.03/lib/HTML/TreeBuilder.pm

Information type	Details
Age	The age of the user
Gender	The gender of the user
No. of days	Number of days the user had been a member (calculated from the day of account registration till the latest day the user logged on).
Looking For	What kind of relationship the user is looking for from IMVU (optional choices: friendship, dating, relationship, chatting)
Relationship	Current relationship status of the user (optional choices: married, divorce, in a relationship, single, seeing someone)
Buddies No	Number of buddies the user has. Buddies are similar to friends on online social networking sites such as Facebook. Both users have to agree to become buddies with each other.
Visitors No	The number of users who visited the profile page of the user. When the user encounters someone in the virtual environment, he/she can click on the avatar of the person to view the profile page.
Messages No	Number of messages received. These are messages left by other users and are shown on the receiver's profile page.
Gifts	The number of "virtual gifts" the user has received. In IMVU, a gift is usually a virtual item (such as clothes for avatars) which users can purchase and give to other users.
Generosity	The number of "virtual gifts" the user has given to other users.
Has Special Person	Whether the user has a special person. A special person is usually a romantic partner or close friend in IMVU.
User group Data	The name and description of all the groups the user has joined. Groups in IMUV provide an opportunity for people with a common interest, characteristic or purpose to join and socialize or carry out activities with each other. IMVU also provides a group page where members can communicate with each other through an online bulletin board.

Table 4: A summary of the variables collected and used in this study

Apart from this, further analysis was carried out to examine the characteristics of the user groups joined by older and younger users to give an indication as to the type of activities such users were interested in. Information about these groups was collected through the group's profile page.

Although, group members are able to use this profile page to interact with each other (such as through the bulletin board), most of these groups have a focus on in-world activities (members meet in-world to role-play etc) or have in-world implications (such as groups which creating virtual items for avatars). Therefore, analyzing the information from such groups would give an indication as to how older and younger people use virtual worlds.

4.1.2 Statistical Analysis

To highlight the unique characteristics and behaviour patterns of older users in virtual worlds, statistical analysis techniques were used to compare data in the profiles of older users with younger users. One key point to note is that most of the variables recorded (such as social capital, number of gifts) showed a power law distribution pattern. This is a common occurrence with data collected from users in social network services (For instance, see (Thelwall, 2008)). As such, when using statistical analysis techniques to compare the data, non parametric methods (such as using the Mann-Whitney test in lieu of the T-test) were adopted as the data was not normally distributed. Studies of a similar nature have also used this method to analyze data collected from user profiles of social networks (Pfeil, Arjan, & Zaphiris, 2009).

4.2 Results

In this section, the results from the analysis of the user profiles are presented emphasizing on three aspects: the characteristics of older users, the nature of their activity patterns based mainly on their social network and online gift giving behaviour and the type of activities carried out based on the type of user groups they joined. The results from the younger user's profiles were used to provide a frame of reference so that the unique characteristics and activity patterns of older virtual world users could be identified.

4.2.1 User characteristics

First, the demographics and characteristics of older and younger users were analyzed. The results showed that there were more female than male users for both age groups. Female users constituted 59% of the older users and 64.8% of the younger users. One explanation for this could be due to the nature of IMVU which has more activities catering to female users (such as shopping for clothes to dress up avatars, designing clothes etc). Studies have shown how computer games which have similar activities (such as The Sims or Barbie Fashion designer etc) have been extremely popular among female players (Fron, 2007) and could thus explain the prevalence of female users in this platform.

As for the relationship status of the users, a larger proportion of older people were reluctant to report their relationship status (51.5%) compared to younger people (29%). Of those who did report their relationship status, a majority of the older users were single (51.9%). The same was true for younger users (67.7% of them reported being single). Comparison of the relationship status between the two age groups showed that there was a significantly larger

number of older users who reported being married (23.4% as opposed to 5.1%) or divorced (7.4% as opposed to 0.5%) than younger users. There were also more younger users who reported either being in a relationship (19.8% compared to 12.9%) or seeing someone (6.9% compared to 4.4%) compared to older users. Chi-square tests confirmed that the overall difference in the relationship status between the two age groups is significant ($\chi^2(4) = 337.821$, $p<0.01$). Compared to the general population, there is a smaller proportion of older virtual world users who are married. For younger users, there is a similar proportion (statistics show that 2.2% of users aged 18-19 and 12.3% for users aged 20-24 are married) (US Census Bureau, 2011). Figure 10 presents a graphical summary.

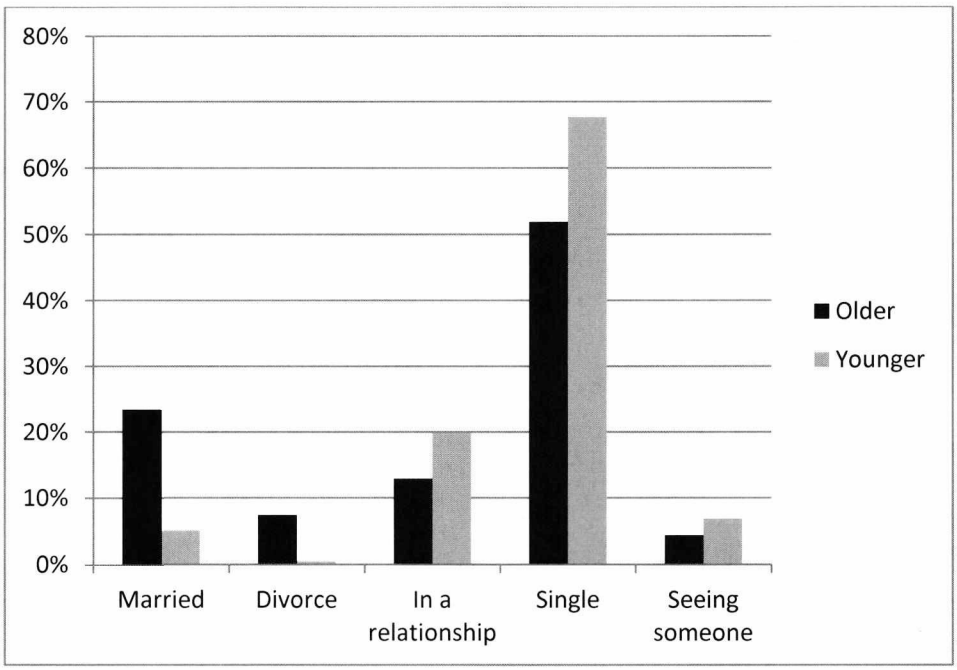


Figure 10: A graph showing the relationship status of older and younger users

Analyzing the membership duration also showed that older people had been accessing this virtual world for a longer period (median of 187 days compared to median of 107 days for younger users) when compared to younger users. Mann Whitney tests showed that this difference between the two age groups was significant ($U(4996)=3,719,064$, $z=11.783$, $p<0.01$). The membership duration for both age groups showed an approximate power law distribution (See Figure 11). This trend is in line with that of other social network sites (Thelwall, 2008).

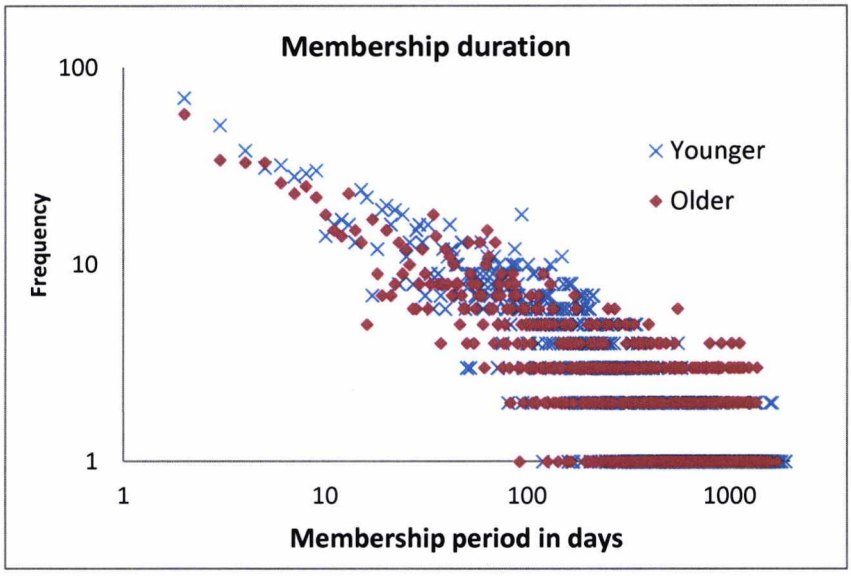


Figure 11: Membership duration for older and younger users (log-log scale)

The user profiles also contained information about what users were looking for in IMVU. Similar to information about the relationship status, a larger percentage of younger people (64%) revealed information about what they were looking for compared to older people (46%). A comparison between the two age groups showed that more younger people were looking for dating (12.3% compared to 10 %), relationships (18.2% compared to 13.8%) and chatting (30.9% compared to 28.2%) than older people. Older people however, tended to be more concerned with looking for friendship in this platform (47.8% compared to 38.5%). Chi-square tests showed that the overall difference between what the two age groups were looking for is significant ($\chi^2(3)= 23.35, p<0.01$). See Figure 12 for a graphical summary.

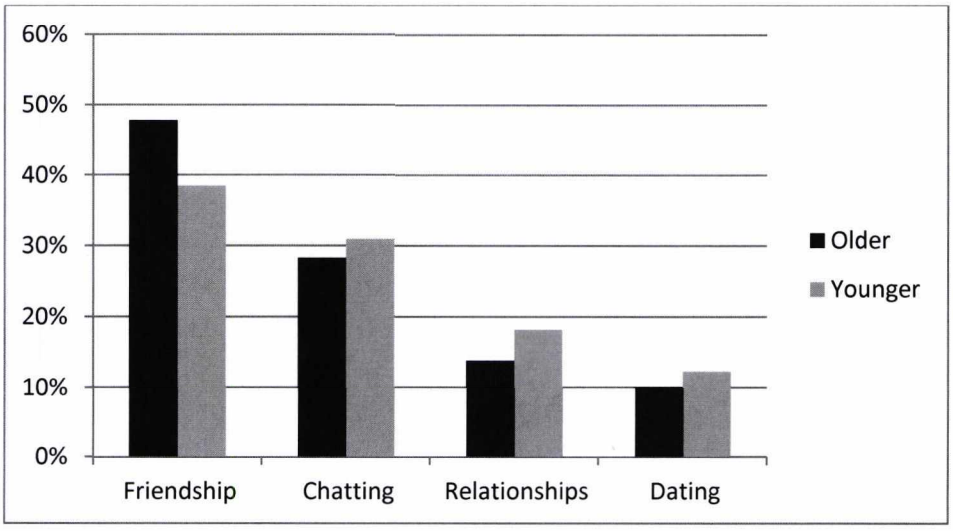


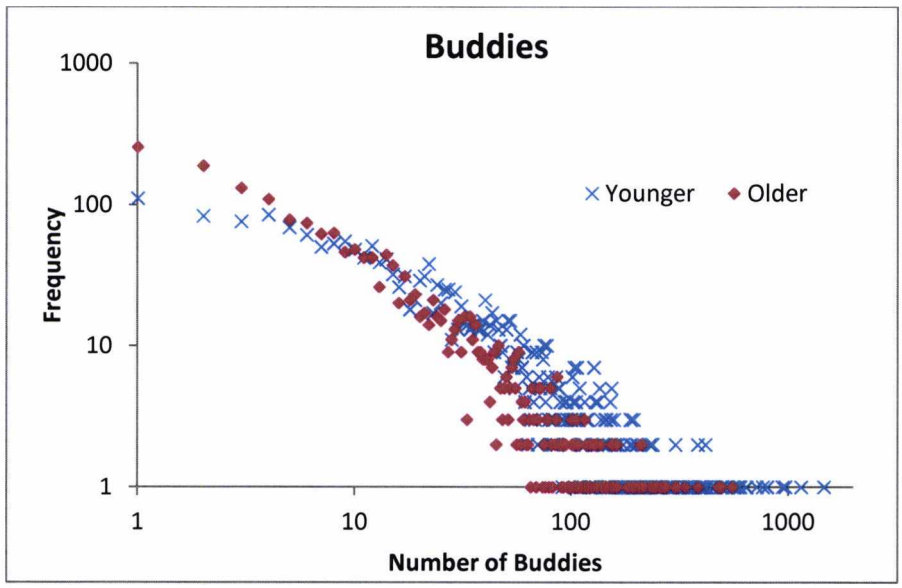
Figure 12: A graph showing the 'looking for' status of older and younger users

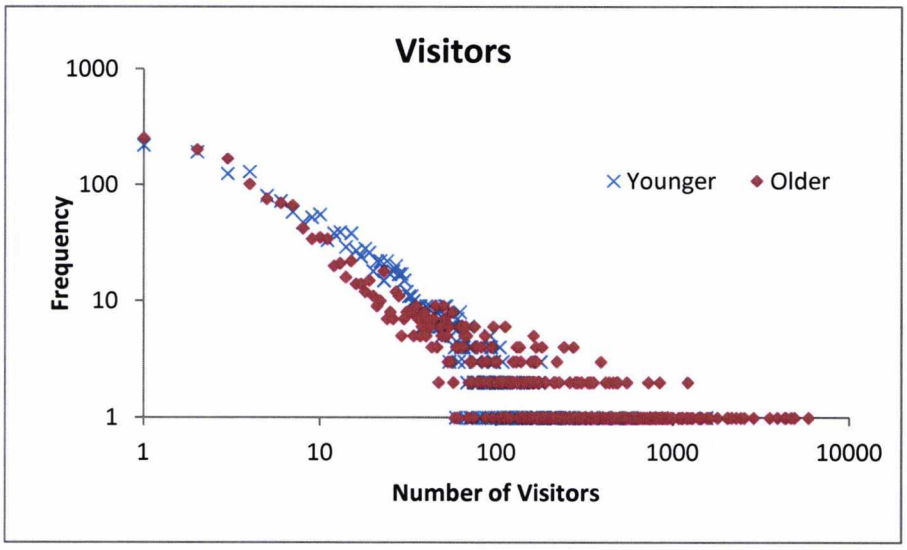
Compared to conventional/non-3D social networking sites such as MySpace, there is also a similar trend in that the majority of the users were looking for friendship (Thelwall, 2008). However, the data seemed to suggest that more users in this 3D platform were looking for

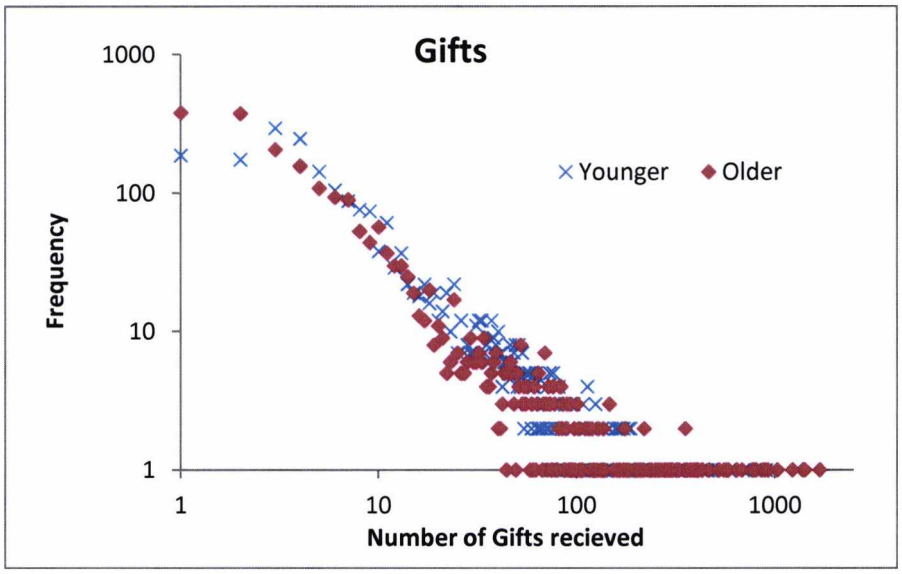
dating and relationships compared to Myspace (Thelwall, 2008). What was particularly interesting about this was that the interest in romantic relationships was not limited to only younger users, as there were a considerable proportion of older users also interested in using this 3D platform for dating. In addition, after examining the data, 9.3% of older people also had a 'special person'. In IMVU, users are able to nominate a single user as a special person. Based on the descriptions provided, this is usually a romantic partner the user interacts with in this virtual world. This provides an indication of how some older people were successful in using this platform to develop and maintain romantic relationships.

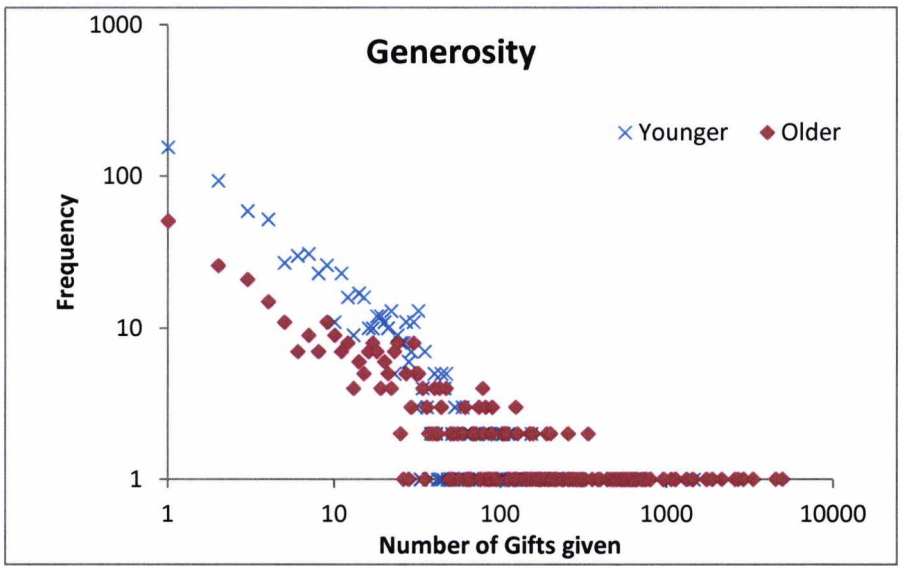
4.2.2 The Social network and online gift giving behaviour

This section examines the activity patterns of older and younger users, focusing on two aspects: online gift giving behaviour (based on the number of virtual gifts each user gave and received) and the nature of user's social networks (focusing on the number of buddies and visitors). Similar to membership duration, these measures also showed a distribution pattern which is similar to the power-law distribution (see Figure 13 for more information).






Gifts
1000
100
10
1
Frequency
Younger
Older
1
10
100
1000
Number of Gifts recieved


Generosity
1000
100
10
1
Frequency
Younger
Older
1
10
100
1000
10000
Number of Gifts given

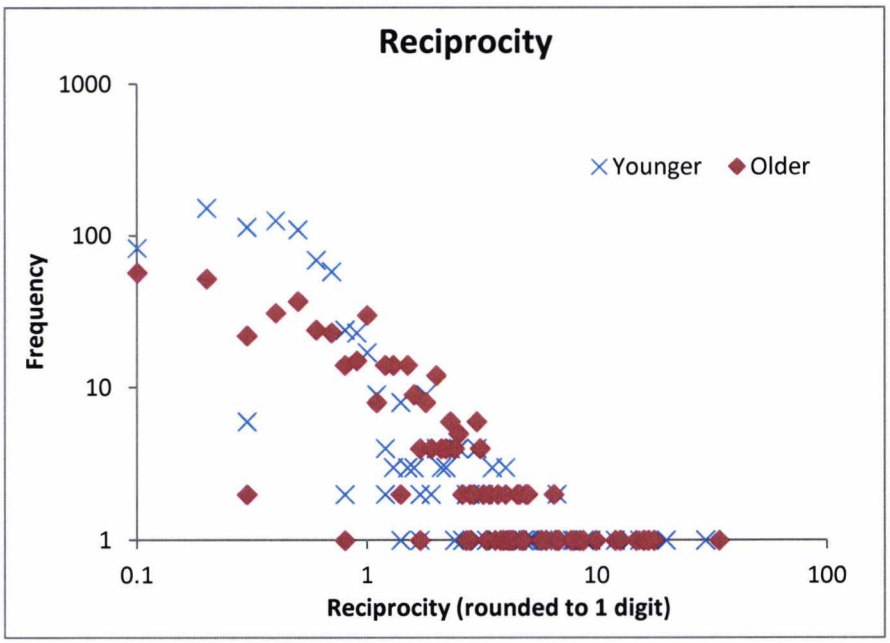


Figure 13: Number of buddies, visitors, gifts, generosity and reciprocity of older and younger users (log-log scale)

4.2.2.1 Online gift giving behaviour

Gift-giving plays an important role in the development and maintenance of social relationships. Giving gifts can help shape social bonds, reflect the level of intimacy in relationships or reaffirm ones' relationship with others (Sherry, 1983). This extends beyond offline relationships into virtual worlds. A study looking into Second Life has found a link between the exchange of free "virtual items" and the strength of social ties (Bakshy, Simmons, Huffaker, Teng, & Adamic, 2010), indicating that gifts could play an important role in enhancing online social relationships. Therefore, the online gift giving behaviours of older and younger people were analyzed in this study. First, the percentage of users in each age group who had given or received gifts in IMVU was examined. The results showed that there were more older people (17.6%) who had never received any gift compared to younger people (8.6%). A similar trend was also observed in regards to gift giving. 77.4% of the older people in this platform had never given any gift compared to only 58% of younger people. Interestingly, research looking at gift giving behaviour in the physical world identified a similar pattern. One study showed that more younger people gave and received gifts (such as presents, help, etc) in a 9 month period compared to older people (Komter, 1996). The large difference in the percentage of those who had received gifts to those who had given gifts for both older and younger people suggests that the majority of the gifts are given by only a minority of the population. Part of this could be explained by the power law effect, where the top 5 percentage of the population gave 88% of the gifts (Even though the number of gifts received also adheres to the power law effect as well, it does so to a lesser degree with the top 5 percentage only receiving 56% of the gifts).

Turning our focus to the number of received and given gifts (from those who had received one or more gifts), the results showed that younger people received more gifts (median=7) than older people (median=6). Mann-Whitney tests confirmed that the difference was significant (U(3759)=1,603,552.5, z=-4.76, p<0.01). However, in regards to the number of gifts given, older people who had given one or more gifts gave significantly more gifts (median = 23) than younger people (median =8). Mann-Whitney tests also confirmed this difference to be significant (U(1380)=289,233.5,z=10.17, p<0.01). This does not seem to be due to the fact that older people were members for a longer period than younger people as a correlation test showed that membership period was only weakly correlated with generosity/gift-giving (spearman's rho= 0.27, p<0.01). A study in offline gift giving shows a similar result (Midlarsky & Hannah, 1989). The study found that when time and effort instead of financial resources was used, older people were found to be more generous than younger people. As virtual currency which is used to purchase the gifts in this platform can also be obtained through the expenditure of time and effort (such as by participating in contests or creating and selling items), based on Midlarsky and Hannah's study, I speculated that this could be one reason why older people gave more gifts than younger people.

Another important aspect of gift giving is reciprocity. Overall, there seems to be a high correlation between the number of gifts given and the number of gifts received in both age groups (Spearman's rho=0.684, p<0.01). This is in line with research in offline gift giving behaviour, which identified a strong relationship between gift giving and receiving (Komter, 1996). Calculating a reciprocity rate based on the ratio of gifts given to gifts received for those who gave and received at least one gift, the results showed that older people had a significantly higher reciprocity rate (median = 0.68) than younger people (median=0.38),(U(1380)=275,252.5,z=8.172,p<0.01). One study investigating reciprocating in the physical world found that older people give gifts to "secure a sense of control by relying on the norm of reciprocity in gift giving" which would help compensate for the reduction of power and control in their roles due to aging (Mathur, 1996). This could explain why older users in this virtual world have a high rate of reciprocity as well, if they give gifts in expectance of receiving future assistance, they too might be more inclined to reciprocate to the favours of others. The high level of reciprocity among older people might also reflect a strong relationship with their ties as previous studies have argued that reciprocity has been used by older people to strengthen weak ties and was an important determinant of close relationship (Lehtinen, Nasanen, & Sarvas, 2009).

4.2.2.2 The social network of users

One benefit ascribed to online social networks was that they helped create social capital for users. One study showed how students were able to use social network sites like Facebook to create and maintain bridging social capital and (although to a lesser degree) bonding social capital (Ellison, Steinfield, & Lampe, 2007). In this chapter, the social networks of older and younger users were examined by investigating the number of buddies and visitors each user had. The results showed that older users had significantly fewer buddies (Median = 6) than younger users (Median = 20), U(4326)=1,499,714,z=-20.4,p<0.01. However, older users had significantly more visitors (Median=8) to their profile page than younger users (Median=7),

U(4326)=2,561,491,z=5.42, p<0.01. The higher number of visitors which older users received was most likely due to them being members for a longer period than younger users as membership duration was found to be highly correlated with the number of visitors (spearman's rho= 0.61, p<0.01).

Based on these results, there was an observable divide in the number of ties between the social networks of older and younger users. Younger users on average were connected to more users than older users. A similar divide can also be identified in other social networking services such as MySpace as well (Pfeil, Arjan, & Zaphiris, 2009). Pfeil et al (2009) suggested that one reason older people have a relatively low number of friends in social networks sites might be because they are more concerned with the strength of ties rather than the number of ties. This might be the case for older user in this virtual world as well. Therefore, the amount of interaction between older and younger users and each of their buddies were examined. The number of gifts given and received per each buddy the user had (calculated by dividing the number of gifts given with the number of buddies) were analyzed. The results showed that older users who gave at least one gift gave more gifts per each buddy they had (Median=1.26) compared to younger users (Median= 0.216) (U(1372)=317,533.5, z=14.7,p<0.01). The results also showed that older users received significantly more gifts per each buddy they had (Median=0.875) than younger users (Median=0.377), U(3958)=2,457,390, z=14.05, p<0.01. When looking at the number of messages received (messages are comments which users send to each other and are displayed on their user profile), older users received significantly more messages per each buddy they had (Median=0.46) than younger users (Median=0.19), U(2554)=523,850, z=15.62, p<0.01). All this seems to suggest that there was a higher degree of interaction between older users and each of their buddies when compared with younger users.

4.2.3 User groups

Analysis of the types of user groups joined by older and younger users was carried out to examine their interests in the activities in the virtual world. From the data, approximately 1100 different groups were identified from the profiles of older users and 900 different groups were identified from the profiles of younger users.

Content analysis, a method which allows for systematic and objective quantification of contents into categories (Bryman, 2004) was used to categorize the user groups. First, the textual descriptions of the groups (such as "*This is a group for people interested in software X, if you want to know about this software, then this is the group for you to join*") were analyzed and categories were created to describe the main purpose of the groups. Similar categories were then combined and the groups were re-examined based on the newly integrated categories. Overall, 13 categories were identified from the analysis (See Table 5 for more information). To ensure consistency in the coding process, Inter-coder reliability tests were conducted with 2 coders on a randomly selected subset of the user groups (N=110, accounting for 5% of the total data set). An average Kappa coefficient of 0.715 was obtained from the reliability test, which is deemed satisfactory (a coefficient score of 0.7-0.89 indicates high correlation and acceptable inter-coder reliability (Bryman & Cramer, 2005)).

The categories were then mapped according to the components of user motivation proposed in section 2.6.5. The three components are: Achievement, Social and Immersion. The 13 categories were then placed under one of these components. The motivational components were adapted to suit the context of use in IMVU. Achievement-oriented user groups refer to groups which focus on activities such as competing in contests (such as contests for the best dressed avatar), purchasing virtual items (to enhance their in-world status through avatar and virtual room customisation) and learning how to create virtual items. Social-oriented user groups are groups for social interaction and relationship building. In IMVU, this included user groups in which users with similar interests (such as music, photography etc), similar user characteristics (such as those from the same ethnic group) get together to socialize. Finally, immersion-oriented user groups consist of groups where users engage mainly in fantasy and role-play activities.

Parent category	Category	Description
Achievement	Creating stuff	User groups for virtual items creation, such as virtual clothing, furniture, etc
	Shopping (for virtual items)	User groups for receiving updates about certain products from the developers and for finding virtual items to purchase
	Contest	User groups which users join to participate in competitions or contests to win prizes such as virtual currency (Users in IMVU host regular avatar costume contests and quiz show contests).
	Learning	Groups for users to improve their skills on a specific topic such as computer programming (for instance, groups teaching users to use the GIMP graphic editing program)
	Collecting-sharing	User groups centred around virtual collectables (stamps, badges etc) in IMVU
Social	General community	General social groups, for general chats without a specific theme
	Personal groups	User groups with a relatively small number of members which are usually focused on the group owner. These groups tend to be centred around "family" or "close friends of a specific user"
	Regional group	Groups for users of a certain ethnic group or nationality
	Shared interest group	User groups for people with similar interests such as in music, games or sports etc
	Romance & Dating	User groups specifically created for those interested in dating and romantic relationships
	Health & Support Group	Support groups such as groups for people with depression or those who suffer from a specific disease
	Themed chat room	User groups centred on a virtual location (such as a pub, beach etc) in IMVU. Regular visitors of that location usually join these groups.
Immersion	Role-play	User groups for people interested in role-playing activities. popular role-playing activities include role-playing as fantasy creatures, sci-fi characters or members of a gang

Table 5: A description of the categories of the groups joined by users

The data showed that a number of users (18.6% for older users and 16.1% for younger users) joined one or more user groups in this platform. Older users joined on average (median) 2 groups (Max=102) compared to younger users who joined on average (median) 1 group (Max=22). Mann-Whitney tests showed that this difference was significant ($U(870)=109{,}718.5$, $z=4.528$, $p<0.01$).

Next, the differences between the types of user groups joined by older and younger users were examined. As each user could join more than one user group, the ratio of each user group category was calculated by dividing the number of groups joined in each category with the total number of groups joined by the user. This was done to prevent individuals who joined a very large number of groups from biasing the results. Mann Whitney tests on these group ratios show that older people joined more social ($U(763)=86{,}844.5$, $z=5.016$, $p<0.01$) and achievement type user groups ($U(763)=80{,}027$, $z=2.923$, $p<0.01$) when compared to younger people. Younger people joined more Immersion type groups than older people ($U(763)=53{,}122$, $z=-7.312$, $p<0.01$)).

The effect of gender could also be observed in group participation. Although no significant gender difference in the type of groups joined by younger people was identified, for older people, Mann-Whitney tests showed that more older males joined social type groups than older females ($U(413)= 17{,}675.5$, $z=-3.074$, $p<0.01$) , while older females tended to join more achievement type groups ($U(413)= 25{,}612$, $z=4.00$, $p<0.01$) than older males. This was contrary to the users of online massively multiplayer games, which found that males tended to be motivated by achievement factors (Yee, 2006). One possible reason is the difference in the nature of the platform under investigation, where achievement in IMVU is mostly tied to activities favoured by females such as fashion modelling contests or creating virtual clothing. Similarly, in other virtual environments such as Second Life, people who favoured such activities also tended to be female (Fron, 2007). Another possible explanation is that this is a unique characteristic for older users, that older females inherently prefer achievement type activities, as this difference was only identified in the older user's age group. Figure 14 shows the percentage of the type of groups joined by older and younger users.

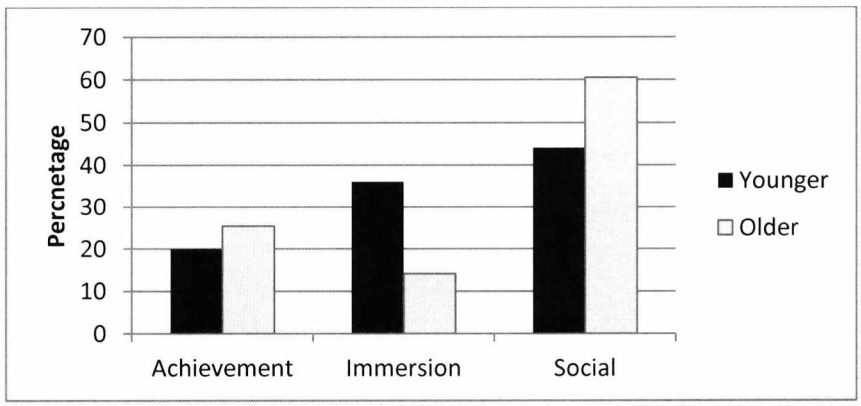


Figure 14: The percentage of the type of groups joined by older and younger users

Figure 15 shows the difference in the categories of user groups which older and younger users joined. The most popular type of user groups that younger people joined are *role-*

playing groups. For older users, the most popular type was *shared interest group*. Older people also joined more groups related to developing virtual items such as groups that users join to learn how to use specific software to create items (*learning*) or groups that users join to discuss the development of virtual goods (*creating stuff*).

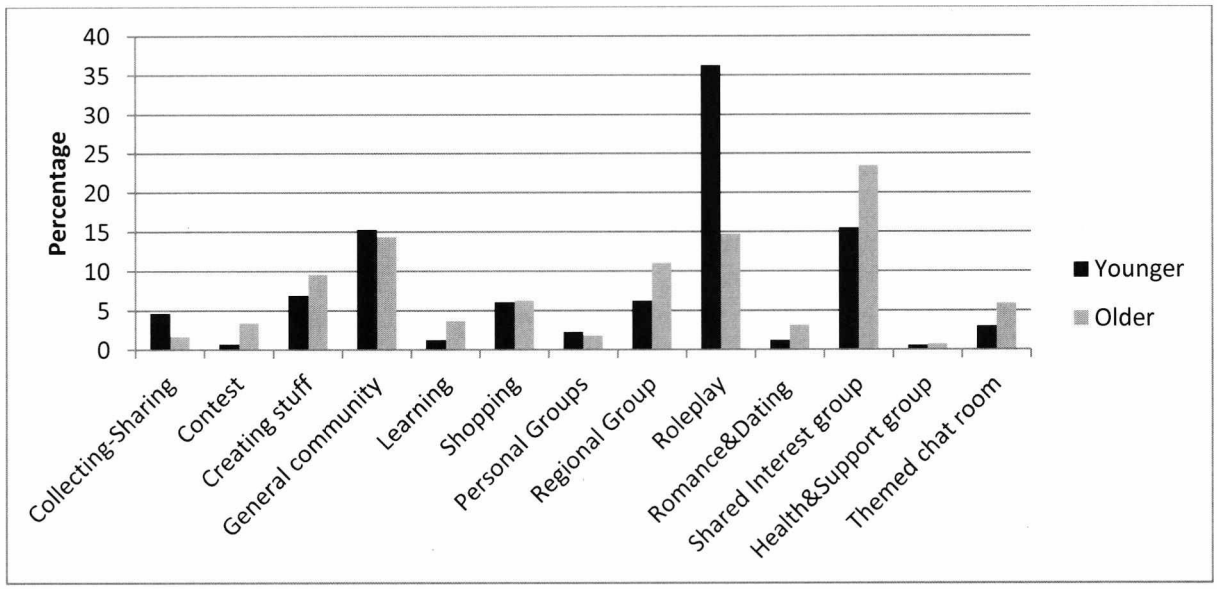


Figure 15: The percentage of the categories of groups joined by older and younger people

The shared interest groups could be further broken down into eight sub-groups as shown in Figure 16. Overall, younger people preferred to join shared interest groups mainly on topics such as games, music and TV and older people joined more "religious" or "educational" groups such as those which are related to a certain skill or knowledge field (such as photography, geography, history etc).

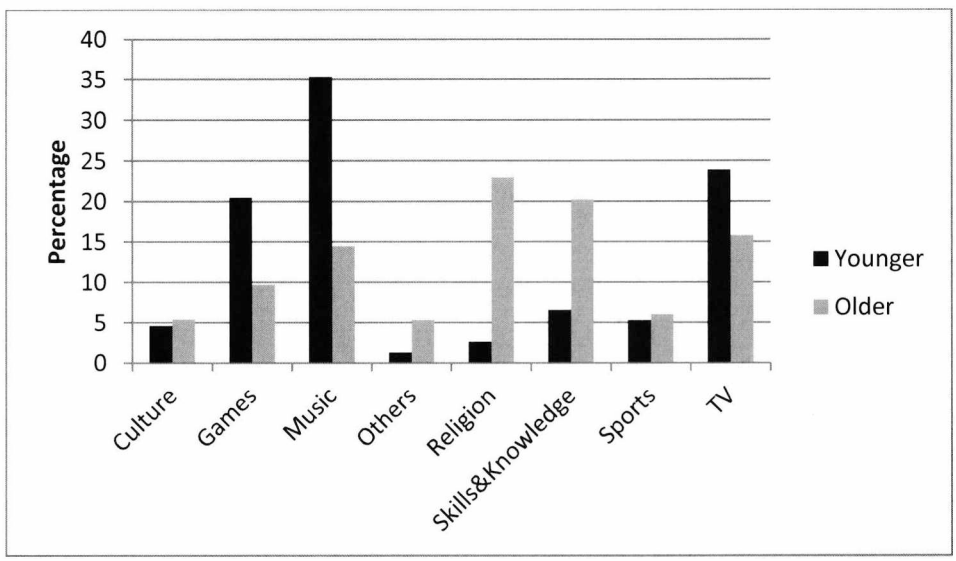


Figure 16: The type of shared interest groups joined by older and younger users

The overall difference in the type and category of the groups joined by users of both age groups seems to indicate that younger users participated in more groups for "playful"

purposes (for instance, role playing groups and shared interest groups on entertainment related topics) while older users participated in more groups which had "serious" purposes as well as groups which had a clear relation to their physical life (for instance, special interest groups on religion, education and specific skills). Overall, this would seem to imply that older users are interested in using IMVU to extend their physical life through virtual activities which are analogous to physical world activities. In contrast, more younger users prefer activities which act as a form of escapism from their physical life. This is also reflected in the type of groups which the users joined as older users predominately joined social type groups (61%) with only a small percentage of them joining immersion type groups (14%). Compared to this, younger users joined considerably more immersion type groups (36%) and considerably less social type groups (44%).

I believe that this behaviour is in line with how older and younger people use computers and technology in general. For instance, one survey found that more younger people used the internet for entertainment purposes (listening to music, playing games etc) compared to older people, while older people tend to use the internet more to obtain beneficial information (about health, religion and news etc) (Jones & Fox, 2009). One study looking at the attitudes of older people with social network services found that older people perceived computers as being a tool for work rather than for fun because most of them became familiar with computers in a work context (Lehtinen, Nasanen, & Sarvas, 2009). This might explain their inclination to participate more in "serious" activities than "playful" activities and therefore join more groups catering to those activities.

Another interesting result was that older people were interested in learning about the tools and process for creating virtual items by joining groups, even though this is usually a complex process which requires a considerable level of technical experience with image editing and 3D modelling programs. It was reported that apart from developing social relationships, one of the reasons older people started participating in online communities was to find help and encouragement in learning more about computer technologies and improving their technical skills (Kanayama, 2003). In a similar manner, this could be why a considerable number of older users were interested in participating in groups in these categories, to find a supportive social avenue to discuss and learn about technology.

4.3 Conclusion and Chapter implications

This chapter describes the results of a study which was carried out to analyze data from the profiles of older and younger users in a virtual world, IMVU. The main aim of this study was to provide empirical data on the demographics, interaction and activity patterns of older users in virtual worlds. Overall, data from more than 2500 profiles of older users were analyzed.

The key findings from this analysis are:

- Similar to their younger peers, older users were predominately looking to use virtual worlds for friendship. What was more interesting was that a considerable number of such users were also interested in using virtual worlds for purposes such as dating. Some even indicated that they had a special person in this platform.

- Despite having a smaller number of ties than the typical younger user, older users have a higher level of interaction (gifts given and received, messages received etc) between each tie which suggests a stronger relationship.

- Overall, a smaller proportion of older users gave and received gifts. However, for those who gave gifts, older people gave significantly more gifts than younger people. In addition, older people had significantly higher levels of reciprocity.

- Analyzing the categories of the user groups gave an indication as to the type of activities older and younger users were interested in. While younger users preferred immersion type groups with activities such as role-playing, older users predominately preferred to join social type groups.

- Despite the ability of virtual worlds to construct alternative realities, a feature well embraced by younger users, older users seemed more interested in participating in activities which augment their physical life. This was evident from the larger percentage of older users who joined groups to connect to users with similar physical world interests or to learn about a technology.

Overall, this study has identified a number of unique trends in how older people engaged with virtual worlds. Independently, the contribution of this study was to provide empirical data about how older people have engaged with virtual worlds, a topic which has received little attention in the present research community. Although, studies have been carried out to examine age related differences with technologies such as social networks (Pfeil, Arjan, & Zaphiris, 2009) and Usenet groups (Zaphiris & Sarwar, 2006), this study focuses on virtual worlds, a technology which allows for more complex and diverse user interactions. The findings from this study were then combined with the findings from the study in the previous chapter. Key results on the interests, activities and characteristics of older users in virtual worlds are discussed in section 8.1.

It should also be noted that there are other research methods that have been proposed to analyse power law distributions in more detail. For instance, researchers in the field of cybermetrics have used the maximum likelihood method and the Kolmogorov-Smirnov goodness-of-fit metric to calculate the best power-law fit which was used to compare the characteristics of in and out degrees in online social networks (Mislove et al, 2007).
Some researchers however believe that such techniques are controversial (Thelwall, 2008).

Such techniques are beyond the scope of this thesis and the results of more conventional statistical analysis (Mann-Whitney tests) were reported in the main analysis. However, two-sample Kolmogorov-Smirnov Z tests were also carried out to examine the differences in the distribution of the membership period, gifts given, received, number of buddies and visitors. The results are consistent with the Mann-Whitney Tests, showing a significant difference in the number of Gifts received ($Z=3.75$, $p<0.001$), Gifts given ($Z=4.63$, $p<0.001$), Buddies ($Z=8.64$, $p<0.001$), Visitors ($Z=4.75$, $p<0.001$) and Membership period ($Z=6.92$, $p<0.001$) between older and younger users. Similar to Mislove et al's (2007) study of online social networks, these variables were also fitted with a power law model calculated using a program created by a python library (Jeff et al, 2013). The estimated power-law coefficient (alpha) along with the Kolmogorov-Smirnov goodness-of-fit metric (D) were calculated. For younger people, the results were alpha=3.98, D=0.06 for number of buddies, alpha=2.70, D=0.03 for number of visitors, alpha=2.10, D=0.07 for membership period, alpha= 1.70, D=0.04 for gifts received (one or more gifts) and alpha=2.02, D=0.03 for gifts given (those who gave one or more gifts). For older people, the results were alpha=2.40, D=0.08 for number of buddies, alpha=2.55, D=0.04 for number of visitors, alpha=5.68, D=0.17 for membership period, alpha= 1.69, D=0.04 for gifts received (one or more gifts) and alpha=2.31, D=0.07 for gifts given (those who gave one or more gifts). The low goodness-of-fit metrics indicate a good fit for the power law models for the coefficients used (Mislove et al, 2007).

The results from the two studies show that social interaction is a key component in both the reason older people use virtual worlds and in the type of activities which were beneficial in supporting healthy aging. For instance, in the interview study, users overwhelmingly cited social purposes as their main motivation in using virtual worlds (see section 3.3.1). Most of the activities which older people reported carrying out (such as teaching classes, being taught about programming etc) also had a social component. In addition, analysis of the user groups also found that social type groups were the most popular type of groups with older virtual world users. As such, the second part of my research (research questions 2 and 3) focuses on social interaction.

Chapter 5: Development and testing of a virtual environment tool for use in experiment studies with older people

In the previous chapters (chapters 3 and 4), I have analysed the characteristics, interests and activities of older people who are users of virtual worlds. I have also described some of the potential benefits of virtual worlds in supporting healthy aging. From these studies, I have identified social interaction to be a key component in the activities carried out by older people in virtual worlds.

The later chapters (6 and 7) in this thesis would focus more on this component. The main aim is to investigate how social interaction in virtual worlds could be improved for older people. To do so, I plan to carry out experiment studies to:

- Investigate age related differences between older and younger users in social interaction in virtual worlds. In particular, I would investigate age related differences in commonly explored concepts such as presence (social and physical) and investigate age related differences in non verbal social behaviour displayed in virtual worlds. This is the main objective of the study carried out in chapter 6.

- Investigate what and how various aspects of the virtual world (the 3D environment, the avatar etc.) and of older users (attitudes, computer anxiety etc.) affect social interaction experience. This is the main objective of the study carried out in chapter 7.

- Provide suggestions on how social interaction could be improved in virtual worlds for older people. This could be found in section 8.3.

One key problem in conducting experiments to explore the aforementioned factors is that there are only a small minority of older people who are currently using virtual worlds (Pew Research Center, 2010a), (The Second life Survey, 2007). Therefore, I would need to carry out experiment studies with older people who might not have much experience with virtual worlds and 3D technology. The commercial virtual worlds used by most studies investigating social interaction and behaviour (as seen in (Harris & al, 2009), (Dotsch & Wigboldus, 2008)) could be difficult for older people to begin to learn and use. This is due to the high learning curve of such virtual world systems. For many people, it is inherently difficult to understand 3D spaces and to perform actions in a simulated 3D environment (Gude, 2006), (Pfeil, Ang, & Zaphiris, 2009). Even younger users who are familiar with computers find them hard to use (Pfeil, Ang, & Zaphiris, 2009). Older people who have reduced cognitive ability and a lack of computer experience would find it more difficult to engage with this technology. Therefore, I needed a simpler virtual world system which such users are able to learn to use in a short period of time.

This chapter describes the process used to develop such a system. This system was used to carry out experiments to study the social interaction of older people in virtual worlds (described in chapters 6 and 7). Overall, the process could be divided into 4 phrases:

1. A focus group session was carried out with a group of older users to identify concepts in designing an appropriate virtual world system and experiment procedure for the study.

2. A set of tools used for creating 3D virtual environments were evaluated and used to develop the virtual world system based on the concepts derived from the focus group.

3. The experiment procedure (including the tasks which participants were asked to carry out) was designed.

4. The system and experiment procedure was tested iteratively with pairs of older users to address any usability issues and refine the experiment procedure.

5.1 Focus group study

A focus group study was carried out with 5 older people (who had not participated in the two previous studies) to identify concepts in developing an appropriate virtual world system for use in experiment studies. The participants in this focus group were different from those in the previous chapters in that most had little experience with computer games and virtual worlds. In the focus group, participants were given hands-on experience with a virtual world, IMVU and were then asked to discuss their experience of using the virtual world.

5.1.1 Study Procedure

The focus group session lasted approximately 2 hours and 15 minutes. The study was divided into 5 steps:

1. The overall purpose of the research project and the purpose of the focus group session were explained to the participants.

2. Participants were asked to introduce themselves to each other and discuss their experience and opinions towards computer games and why they have or have not used them. Participants were also asked how they prefer to socialize with their family and friends and were asked how they used technology in communication.

3. Two short introduction videos (official trailers of the virtual worlds IMVU and Second Life) were shown to introduce participants to the concepts of virtual worlds. Participants were then encouraged to discuss their opinions and impressions towards the virtual worlds they had seen in the videos.

4. Participants were divided into three groups (two groups had two participants and one group had one participant) and were given hands-on experience with IMVU. Participants were given training on how to select and customize their avatar, navigate around the virtual world and start private and public chats. Participants were then allowed to play freely for 25 minutes (a facilitator was appointed to each group to help answer questions and resolve technical issues).

5. Several open-ended questions were used to encourage participants to discuss their experience with the virtual world they had just used. Participants were asked to discuss which part of the virtual world experience they found interesting and what difficulties they encountered. They were also asked to give ideas on how virtual worlds could be designed to be beneficial for them.

5.1.2 Findings from the focus group study

5.1.2.1 Participant characteristics

Table 6 summarizes the characteristics of the older people who participated in the focus group study.

Name	Age	Gender	Experience with computer games	Main method of social interaction
Participant A	62	F	None	Face to Face
Participant B	62	F	Casual games[21]	Face-to-Face E-mail
Participant C	70	M	None	Face-to-Face E-mail & Phone
Participant D	73	M	None	Face to Face
Participant E	62	F	Casual games	Face-to Face E-mail

Table 6: A summary of the characteristics of the older people who participated in the focus group study

Overall, most opinions towards computer games were negative. The main reason seemed to be that participants felt playing computer games was too time consuming. Two participants

[21] Refers to computer games which are easy to understand and could be played in short sessions. These include games such as puzzle games (see (Casual games discussion, 2007)).

even mentioned that playing games made them feel "guilty" as they felt they should be doing something more useful. One participant compared computer games to traditional board games which they felt were social activities and were disappointed as they felt that computer games were activities which could only be played alone (against a computer not with a real player). Of those who did play computer games, participants only played casual games, mainly because such activities did not consume much time. Participants preferred casual computer games which were based on board games (scrabble etc) or puzzle solving games (such as quizzes and brainteasers) because they felt this helped them maintain their cognitive skills.

Participants were also quite anxious about computer technology, having concerns about privacy and were afraid of engaging with it due to the fear of making irreversible mistakes. Most saw computer technology as a tool to be used in a formal work context: two reported using the internet but only to browse for information and another used Facebook but only to promote their business and not for social interaction. Part of this anxiety towards computer technology seemed to be the reason they did not use computer games and other online communication tools apart from e-mail. For example, participants reported being afraid of installing new programs (such as Skype) as they felt this could cause negative implications to their computer (such as introducing malicious programs).

Participants prefer to communicate face-to-face and prefer to socialize with friends by participating in activities together (such as dining, taking part in church activities etc). E-mail was occasionally used, but more to communicate with younger members of their family (one participant mentioned that friends of their age had no access to computers and could only be contacted by phone or by face-to-face meetings).

Overall, the way older people in this study use communication technology and computer games, as well as their opinions towards such technologies seem to be reflective of how typical older people view and use technology. The fear of making mistakes and anxiety towards computer technology reported in this study are common barriers to older people's engagement with technology ((Wagner, Hassanein, & Head, 2010), (Jung et al, 2010)). The use of e-mail and telephone to keep in touch with friends and family members reported by participants also seem to reflect how typical older people use technology to communicate (Dickinson & Hill, 2007).

5.1.2.2 Reception towards virtual world after being presented with the introduction video

One concern raised by all the participants after watching the introduction videos was related to the lack of older looking avatars in the virtual worlds. Participants commented that there were "No Oldies" in these virtual worlds and avatars were stereotypical of the gaming industry, being "Long, Thin and Busty". In general, two participants thought that avatars were off putting, feeling that they have to constantly deceive other people by using young looking avatars. Participants wanted to be represented by a more realistic older looking avatar. One

Participant also expressed interest in the ability to create objects inside the virtual environment, asking frequent questions about how this mechanism worked and seem to enjoy the examples related to the serious uses of virtual worlds (such as in education). This seemed to be tied to their sense of challenge, feeling satisfied with being able to learn something new. The negative preconception towards computer games as being time consuming was also reflected in this discussion. Participants particularly expressed concerns about spending too much time in a "virtual" environment as opposed to the real world and felt that virtual worlds could become an "obsession".

5.1.2.3 Discussion after hands-on experience with IMVU

During the hands-on experience session, participants had a chance to customize their avatars and were shown how to select and purchase clothes and items for their avatars. Participants also tried customizing their own rooms. Afterwards, two participants decided to visit each other's rooms and engaged in private chatting, periodically using animated expressions (such as hugging/waving) mainly for experimental purposes rather than for serious communication. In the end, participants visited a couple of public chat spaces (such as a beach area) to communicate with other online users.

One particular difficulty participants had was in controlling their view point, especially in rotating the camera to focus on their avatars and on objects of interests. Frequent comments were raised in relation to how participants "lost their avatars". Cognitive load problems such as those identified in Ang et al's (2007) study were also frequently observed during this session. Participants were often confused and overwhelmed when too many demands for interactions were placed upon them simultaneously (such as incoming communication requests from multiple partners when they were trying to send their own, trying to navigate their avatars and looking at animated gestures at the same time etc).

Several interesting points were raised during the discussion after the hands-on experience session. The first was related to the sense of artificiality participants felt as they engaged with the virtual environment. As IMVU was represented mainly with cartoon-like avatars and environments, participants felt they were "playing" rather than engaging with the virtual world in a serious manner. Most commented that they felt their experience was "childish" and compared their experience with "playing with dolls". Therefore, participants regularly suggested that they wanted to see more activities with either real world implications or one which gives them a sense of accomplishment (some examples given were a virtual garden). They preferred fixed goal oriented activities (similar to a game) as opposed to open-ended ones. Older participants also again reported young looking avatars as off-putting and preferred avatars to be of a higher fidelity (less cartoon-like) or to be entirely symbolic (one participant suggested the use of "door mice"). Since they perceive the visual aspect of avatar as being unrealistic, it was difficult for them to imagine a real person behind the avatar.

Another aspect was related to the lack of activities and features in the virtual world which older people considered relevant to them. One previously mentioned example was the lack of older-looking avatars. Another was the lack of "plausible" virtual environments. When

visiting public chat rooms, participants overwhelmingly chose those with environments they were familiar with (beaches, waterfronts, clubs) rather than those they were not (fantasy themed or science fiction themed environments etc). In addition, participants also reported wanting to be able to communicate more with older people who shared their interests in the virtual world.

5.1.3 Main guidelines for the design of the virtual world system and experiment procedure

The key points drawn from the focus group session for the development and design of the virtual world system are:

1. Age appropriateness:

    a. Facilities should be provided to allow older people to select or customise older looking avatars, instead of just young looking ones.

    b. The activity and environment should be one based on situations which are "plausible" and familiar to older people (not based on science fiction or fantasy environments).

2. Realism: Higher fidelity environments and avatars should be used. Based on the focus group session, objects should also be designed to be as realistic as possible.

3. Simplicity in accessibility and ease of use :

    a. As participants had considerable concerns about the security implications of introducing new software, the virtual world system under development must be easy to access, preferably without the need to install complicated programs.

    b. A simpler solution in regards to the camera's view point should be designed to allow participants to easily focus on their avatars and objects of interest.

    c. To reduce the demands on cognitive load, the design of the user interface should be kept as simple as possible. Unnecessary features which are not essential for the task in the experiment could serve as a distraction and should be removed.

5.2 Development of the virtual world system

Next, a virtual world system was developed based on the guidelines identified from the focus group study. I decided to develop my own virtual world rather than use an existing commercial virtual world system to carry out the experiments for the following reasons:

1. One of the suggestions from the focus group study was that the virtual world system would need to be simple enough for older people to access and easy enough for them to use. As my experiment plans to focus on a particular aspect of virtual world interaction, namely social interaction, most of the features available would not only be unnecessary, but might also serve as a distraction in the context of the studies. Developing my own system would allow me to design a more simplified user-interface and include only the necessary functions.

2. A self-developed virtual world would allow more data to be collected. Data such as the user position, orientation and chat information could be automatically logged from the virtual world and would be extremely useful in studying the behaviours of older people in social interaction (such as gaze angle and proxemics (see (Smith, Farnham, & Steven, 2002), (Yee, Bailenson, Urbanek, Chang, & Merget, 2007)).

3. Commercial virtual worlds might be hard for older people to access. Virtual worlds such as Second Life or IMVU require users to install a specialized client program. Users must also navigate through a complex menu system and go to a specific area in the public virtual world to access the location created to run the experiment which is not always easy.

5.2.1 Evaluation of Software tools and programming libraries for developing the virtual world system

Two solutions were evaluated in the development of the virtual world system. The first was Opensims[22], a pre-developed open source virtual environment system based on the Second Life platform. The second solution was based on Unity3D[23] and SmartfoxServer[24]. The former is an integrative development tool for creating 3D computer games and interactive applications and the later is a middleware server program for developing massively multi-user applications. Prototypes of both systems were created and tested on a Windows 7 server. Screenshots of both prototypes are shown in Figure 17.

[22] http://opensimulator.org/wiki/Main_Page
[23] http://unity3d.com/
[24] http://www.smartfoxserver.com/

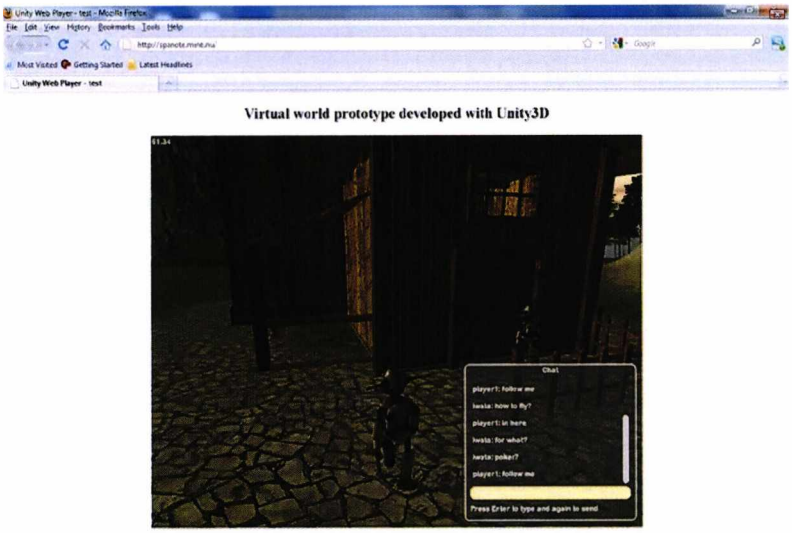


Figure 17: A screenshot of the two prototypes. The prototype created from Unity3D and SmartFoxServer is shown above and the prototype created from OpenSims is shown below.

After evaluating the two prototypes, the Unity3D and SmartFoxServer solution was chosen over the OpenSims solution, the main reasons being:

1. *Flexibility*: Unity 3D allows user interfaces to be customized more easily. Developing widgets to add to the user-interface is also simpler. In comparison, to access OpenSims, users need to use client programs which usually have fixed user-interfaces and are hard to customize.

2. *Ease of access:* Virtual environments created by Unity3D can be accessed through most commercial web browser programs (via the Unity web plug-in) and can be designed to work with low performance computers[25]. In comparison, OpenSims requires users to install a client program into their local hard drive and users need to make substantial configurations to access OpenSims.

3. *Ease of development:* Unity3D provides a variety of programming libraries, the most useful being the WWW libraries which allow easy access to resources hosted on web servers, allowing online data logging systems to be developed more easily. In addition, 3D models and animations are more easily imported and configured inside the Unity3D editor, allowing avatars and objects with more diverse characteristics to be easily created.

5.2.2 Development of the initial prototype

The initial prototype consists of three main modules developed using Unity3D, an avatar selection module, a virtual island module and a virtual store module. Users could access these modules through a web browser.

5.2.2.1: Avatar selection module

One of the design guidelines suggested by the focus group study was to provide users with facilitates to choose appropriate avatars to represent themselves. For this purpose, an avatar selection module was created based on Unity3D's character customization demo project[26]. A screenshot of this module is shown in Figure 18. Users are given a choice between five avatars to use in the virtual world (an older male, older female, younger male, younger female and a non-human avatar). As the focus group study indicated older people's preference for more realistic characters, high fidelity 3D models were used (as opposed to the cartoon-like avatars provided by the Unity3D's character customization demo project). A non-human avatar was also chosen mainly in the context of the experiment, to explore the impact of anthropomorphism (see chapter 6 for more information). An animated 3D model of the avatar is displayed in the centre of the room as users select their avatars (See Figure 18).

[25] http://unity3d.com/unity/system-requirements.html
[26] http://unity3d.com/support/resources/example-projects/charactercustomization.html

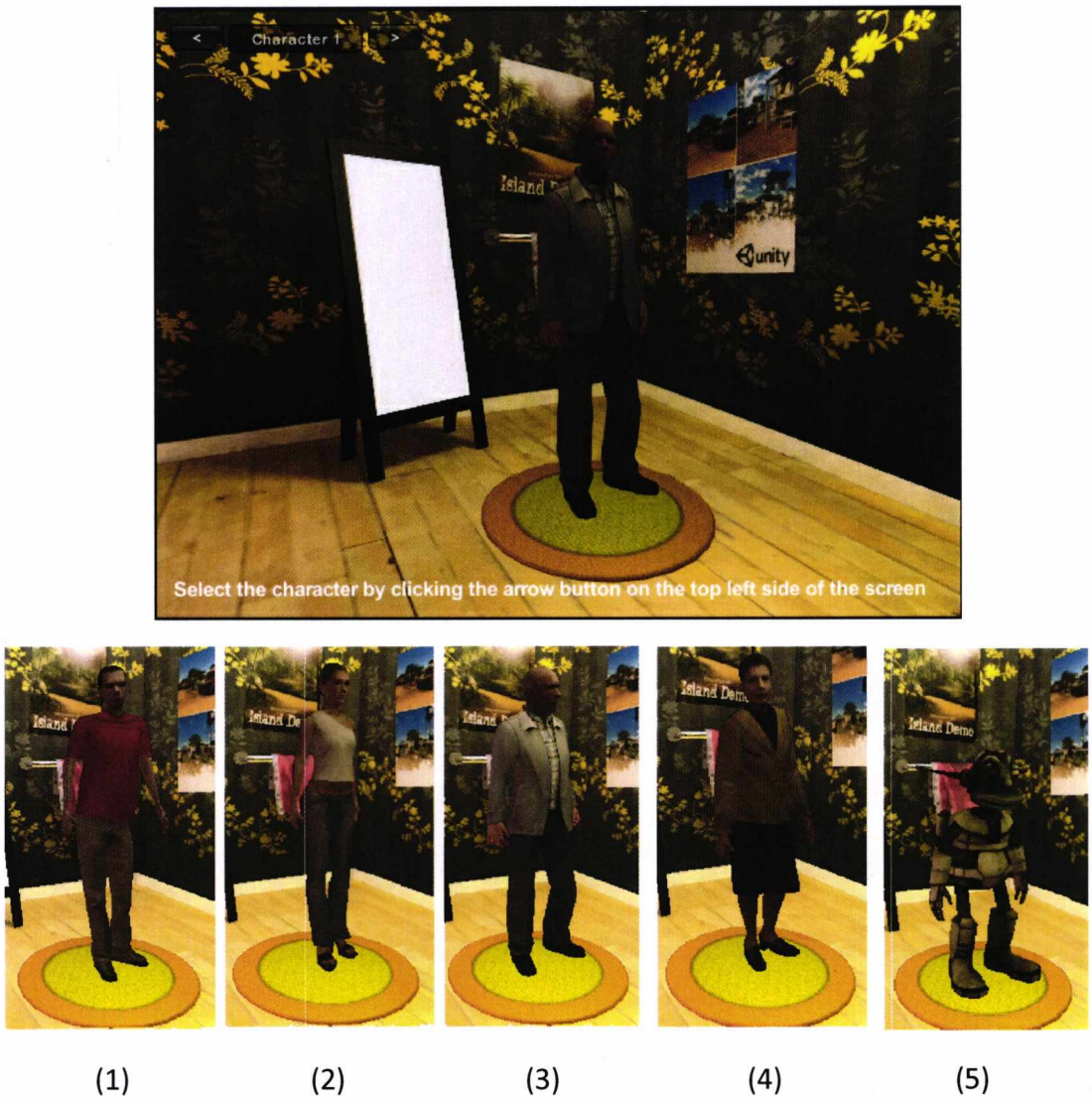


Figure 18: A screenshot of the avatar selection module (Upper) and the five avatar characters which participants can use to represent themselves, shown in the following order: Young male (1), Young female (2), Old male (3), Older female (4) and non-human(5)

5.2.2.2: Virtual island module

During the focus group study, one suggestion offered by participants was using virtual worlds as a tool to survey tourist locations. Building on this idea, the first virtual environment developed for the experiment took the form of a virtual island, simulating a virtual tourism activity.

The island consisted of three houses the users could enter, woods, a lake, a beach and other objects (such as a well etc). Fundamental elements of a multi-user virtual environment such as animation synchronization, text based chatting and collision detection were implemented with the help of SmartFoxPro. To solve the camera view problem (where users had difficulty focusing their camera on their avatars and on objects of interests), users were presented with a fixed third person viewpoint. The camera was placed at a pre-determined position slightly behind a user's avatar. This was done to add simplicity to the system (users now only have to

control their avatar and the camera will move along following their avatar). Navigation was carried out using the arrow keys on the keyboard. Participants communicated with each other by typing in text messages into a textbox and clicking the "send" button. A screenshot of the virtual island is shown in Figure 19. A mini map system was also implemented using a camera to point directly down on the user's avatar from a fixed height.

Figure 19: A screenshot of the initial prototype of the virtual island

5.2.2.3: Virtual store module

The second virtual environment took the form of a 3D virtual store. This environment was designed to replicate an activity older people would be familiar with in their daily lives (i.e. shopping). This design was based on the recommendations identified from the focus group study which suggested the use of age appropriate activities and scenarios. A screenshot of the 3D virtual store is shown in Figure 20.

Figure 20: A screenshot of the initial prototype of the 3D virtual store

Users are able to purchase items in the 3D store by moving their avatars directly towards a shelf with the item they would like to buy. When the user has moved their avatar close enough and is facing the shelf, a product purchase box would appear on the screen showing all the items which the user is able to purchase on that shelf. The user is able to place the item in their shopping cart by clicking on the "pick" button in the product purchase box. Participants are able to view all the products they have in their cart by looking at a list in the "My shopping cart" box. Likewise they are able to view all the products their partner have in their cart by looking at a list in the "Partner's shopping cart" box. Users are able to remove a product from their own shopping cart by clicking on a circular button with the "X" mark located next to the name of the product in the "My shopping cart" box

The shopping system was implemented by running PHP scripts hosted on an Apache server to store and retrieve data in a MySQL database. When the user picks up an item in the virtual store, a PHP script is called to update the shopping cart data in the MySQL database. To synchronize the shopping cart data between the two users, a PHP script is called out every "game second" on both users' virtual store system to regularly retrieve data about their partner's shopping cart and update that data in the virtual store interface.

5.2.3 Hardware Configuration

Web pages were created to embed the virtual environment modules. These web pages could be accessed through a local area network (the pages were hosted on one of the computers used by the participants during the study) and online through the internet (the pages were hosted on a server at the University of Kent). I decided to create an offline solution as I anticipated that internet access would not always be available in some of the homes of older people who could be potential participants in the study. A summary of the hardware configuration used to host the virtual environments are shown in Figure 21.

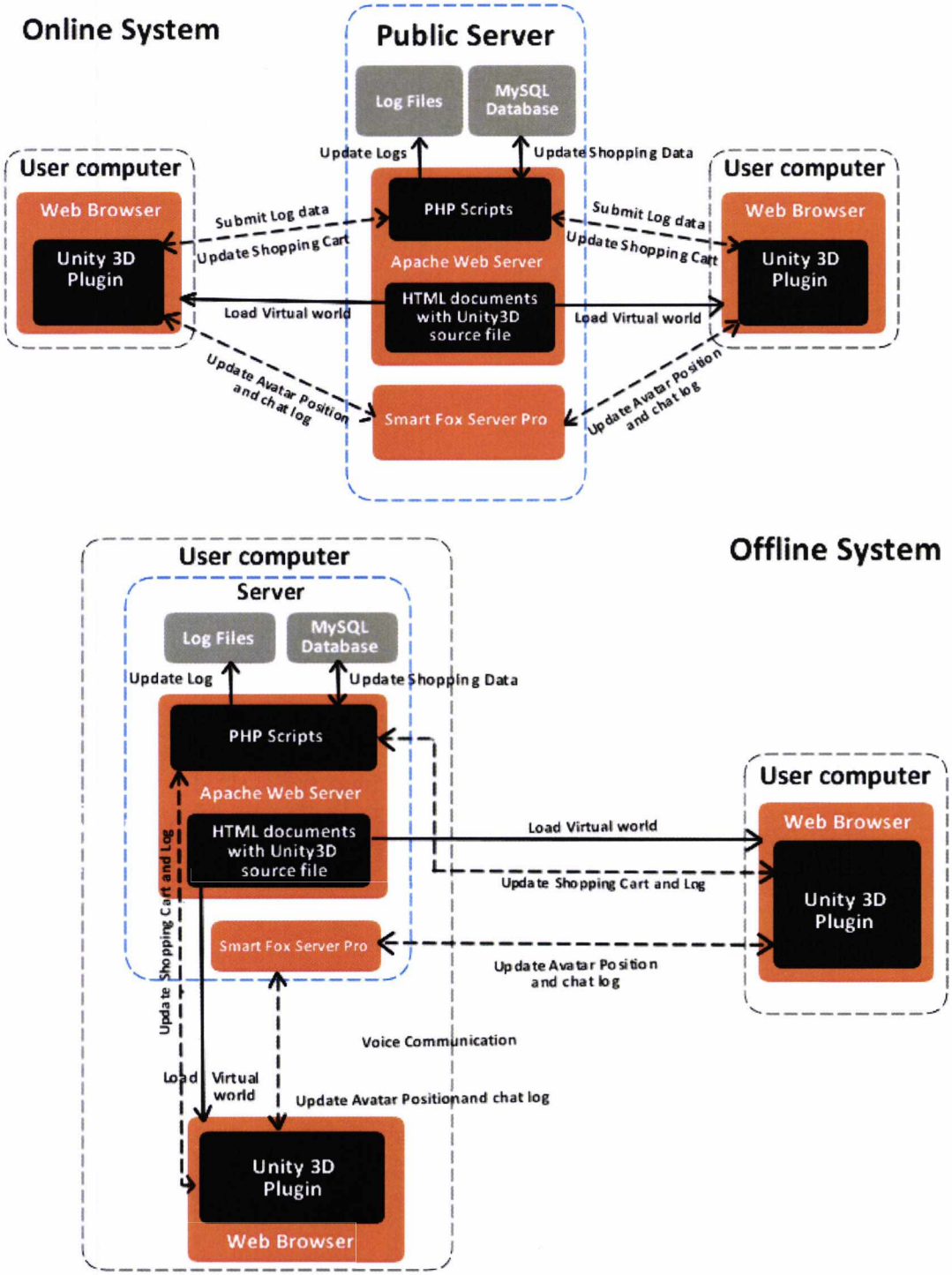


Figure 21: Diagrams summarizing the hardware configurations for the online and offline systems used in the experiments.

In both systems, users are able to enter the virtual world through their web browsers (by accessing a local address for the offline or a public address for the online system). The virtual environments were embedded on web pages designed based on a simple vertical header-body-footer format (See Appendix C and D for examples). First, the user would be directed to a webpage which checks whether the Unity3D plug-in has been installed or not. If not, they would be asked to download and install the plug-in. After installing the plug-in, the user would register for the study and select an avatar. This data would be stored in a MySQL

database. Afterwards, the users would enter the virtual world using the Unity3D plug-in installed on their browsers. SmartFoxPro was used to transmit and receive the position of the partner's avatar and any text messages exchanged. A PHP script and a MySQL database was used to implement the shopping system in the virtual store module as previously explained in section 5.2.2.3.

A system was also implemented to automatically record the location of the users' avatar (in the form of Cartesian coordinates (x,y,z)) and the orientation of the users' avatar (in the form of the yaw angle). This was done by the virtual world system regularly sending the coordinate data (in five second intervals) to a PHP script file located on the server. The data is then promptly stored in a text file. A similar system was also used to log the users' chat information. These logs would be useful in analyzing the behaviour of the users.

5.2.4 Task design

The system which was developed was used to carry out experiments to study the social interaction experience of older people in virtual worlds. Participants were presented with a goal-oriented task to work on as they used each of the virtual environments. The task given in the initial prototype of the virtual island was that participants were asked to imagine that they had arrived on an island and had to explore the island with their partner. They were asked to discuss with their partner and determine a suitable place to set up camp for the night. For the virtual store, participants were asked to imagine that they had to prepare a birthday party for their young nephew (aged 10) and his friends and were asked to cooperate with each other to buy the goods they thought were necessary for the party.

5.3 Testing and iterative development

The prototype of the virtual world system was initially tested and refined with 3 pairs of older users. The purposes of these testing sessions were to:

- Identify and correct any usability issues.
- Pilot the experiment to make sure that the procedure was appropriate and older people could complete the task.
- Ensure that useful information could be obtained from the experiment.

Usability testing was based loosely on the RITE (Rapid iterative testing and evaluation) method. In this method, rapid changes are made in response to any problems that are identified after each testing session, before the software is presented for testing in the next round (Medlock, Wixon, Terrano, Romero, & Fulton, 2002). This method was chosen mainly due to the difficulty in finding a large number of older participants (conventional testing methods could require a larger number of participants) and the relative ease in which improvements could be made and tested.

In each session, the prototype was tested with a pair of older users. These users were asked to first select an avatar (using the avatar selection module) and then to carry out a task in the virtual environments with their partners. Participants were observed as they engaged with the virtual worlds to identify any usability issues. Afterwards, a short interview was carried out with each participant to identify any difficulties participants encountered as they used the system and ensure that the task and experiment procedure was suitable.

5.3.1 Testing of the Initial prototype

Table 7 shows a summary of the key problems and improvements carried out to the system after the testing of the initial prototype. In the first session, participants were only asked to use the virtual island.

Problem	Improvement
Inadequate contrast of colour between objects and their background and inadequate target size of some of the objects	• The size of the avatar selection button was enlarged and the background colour of the button was changed to orange. • The text size in the user interface of the virtual world and the avatar selection menu was enlarged. • The menu interface in the virtual worlds was redesigned, the control panel was removed and the exit button was replaced with one with an image.
During the experiment, participants often forgot details of the task they needed to do	A help button was added to the interface so that participants could refer back to the task explanation
The dynamic mini-map causes cognitive overloads; older people got easily confused as they tried navigate simultaneously using the 2D and 3D map	The dynamic map was removed.
The virtual island map was too wide; a large portion of the island had not been visited by the participants due to the lack of time.	The virtual island map was reduced by half.
During the experiments, one participant had difficulty navigating using the keyboard arrow key buttons. Participants kept looking back and forward between the keyboard (to locate the arrow keys) and the screen.	A small control box which contained buttons (shaped as arrows) that allow users to control the movement of the avatars using the mouse was added (The box is located on the bottom left hand side of the screen as shown in Figure 22).

Table 7: A summary of the key problems encountered and improvements made to the system after the testing of the initial prototype

5.3.2 Testing of the Second prototype

Figure 22 shows a screenshot of the two prototypes which incorporated the improvements suggested by the first testing session. These prototypes were used in the second testing session. Table 8 shows a summary of the key problems and improvements made to the prototypes after the testing of the second prototypes.

Figure 22 Screenshots of the two prototypes used in the second testing session

Problem	Improvement
Several problems were identified with the text base communication system • Participants (including one from the previous testing session) stated their preference for voice communication • Participants lacked the experience in text base communication and sometimes had difficulty in communicating (such as turn taking, taking too long to type etc) • Some participants who have just started to use computers had difficulties with typing	The text base communication system was replaced with a voice base communication system
The arrow keys were too sensitive, causing difficulty in navigation.	The sensitivity of the arrow keys was reduced.
Having a dual mode of control (the keyboard arrow keys and the arrows in the control box) confused the users. Users only tried using the control box for a while then reverted back to the keyboard arrow keys.	The control box was removed.
Users got stuck in certain places in the virtual island.	Changes were made to certain areas in the virtual island. For instance, the depth of the water in the pond was reduced.
Certain questions in the experiment were difficult to answer due to the participant's unfamiliarity with the terms used.	Some of the questions were restructured and improved.
Users had difficulty in locating their partner in the 3D environment	A "Radar" (a 2D arrow which automatically points towards the direction of the partner's avatar) was added to help participants locate their partner more easily (The radar is located on the top right hand side of the screen as shown in Figure 23).

Table 8: A summary of the key problems encountered and improvements made to the system after the testing of the second prototype

After testing the second prototypes, I decided to replace the text base communication system with a voice base communication system. Teamspeak 3, a voice over IP software

which was designed to allow massively multiplayer online gamers to communicate with each other was used to implement the voice communication system. The system was set up so users could connect to the voice server using a Teamspeak client program. After users had connected to the server, a constant voice stream would be established and participants are able to communicate with each other constantly through their headsets in a similar manner as using a telephone. The voice stream ended when participants disconnected their clients from the server.

5.3.3 Testing of the Third prototype

Figure 23 shows a screenshot of the two prototypes which incorporated the improvements suggested by the second testing session. These prototypes were used in the third testing session. Table 9 shows a summary of the key problems and improvements made to the prototypes after the testing of the third prototypes.

Figure 23 : Screenshots of the two prototypes used in the third testing session

Problem	Improvement
Older users expected the products in the virtual store to be categorized and had difficulty finding them when they were not. This made it difficult for them to complete the task.	• The products in the virtual store were re-organized to fit more appropriately with their categories (such as drinks, bakery etc) • Large signboards were put up in the virtual store so participants could more easily locate the products.
Older users who had little experience with computers had no measure to compare their experiences in the 3D store with (they had no experience with online shopping) and were not able to fully evaluate their experience in the 3D store.	A 2D virtual store was developed to allow older users to better compare their experiences and more easily evaluate the advantages/disadvantages of social interaction in a 3D virtual world.
Participants reported the task in the virtual island as being difficult to carry out due to the lack of deciding factors on what would be an appropriate answer for the task. Also, the task was too specific and did not encourage the participants to explore the island enough.	The task in the virtual island was changed. Instead, a more open-ended task was used. Participants were given a scenario in which they won the island and were asked to discuss and come up with a solution on what they wanted to use the island for.

Table 9: A summary of the key problems encountered and improvements made to the system after the testing of the third prototype

After the third testing session, a 2D virtual store was developed. The main reason was that participants found it extremely difficult to evaluate their experiences in the 3D store, as they had little to compare their experiences with (they had never done online shopping before). The 2D virtual store was created to replicate the common experience of shopping in an online store. For consistency, the 2D store contains the exact same product as the 3D store and the products are all placed in the same category. 2D images of the products were created based on a screenshot of their counterparts in the 3D store. To purchase products in the 2D store (See Figure 24 in section 5.4 for a screenshot of the 2D virtual store) users first select the type of products they want to buy from the "Product categories" menu. For instance, if they wanted to buy some oranges, they click on the "Fruit and Vegetables" button in the "Product categories" menu. A list of all the products available in that category would appear in the "Select products" box in the middle of the screen. Users are able to place the item in their shopping cart by clicking on the "pick" button next to the name and picture of the product they want to buy. The system for viewing products already placed in the user and their partner's shopping cart and the system for removing unwanted products from the cart is the same as in the 3D store (see section 5.2.2.3). The graphical interface for viewing the products

in the shopping carts is shared by both the 2D and 3D store. A similar task was also given for participants in the 2D store. Participants were asked to imagine that they had to go shopping for goods with their partner to prepare for a picnic at a local park.

Next, I decided to divide the study into two parts, a virtual store study and a virtual island study (the reasons for doing this are explained in more detail in section 5.6). In the virtual store study, participants were asked to carry out the tasks in the two virtual stores (the 2D and 3D store). In the virtual island study, participants were asked to carry out the task in the virtual island. The virtual island was selected to be done online due to the lower complexity of the task (the virtual store task required users to interact with the more complex shopping system) and the lower system requirement (the large number of objects in the 3D virtual store required substantial computing and graphical processing power to display which older people's computers might not have).

Voice communication was not available in the virtual island study as this required participants to install and configure voice communication software and required the use of extra hardware such as headsets. This would add too much complexity to the study and would limit those who are able to participate. Text based communication was not perceived to be much of a problem as older users who could participate through the internet would likely already have adequate typing skills (as they would already know to use the internet) .

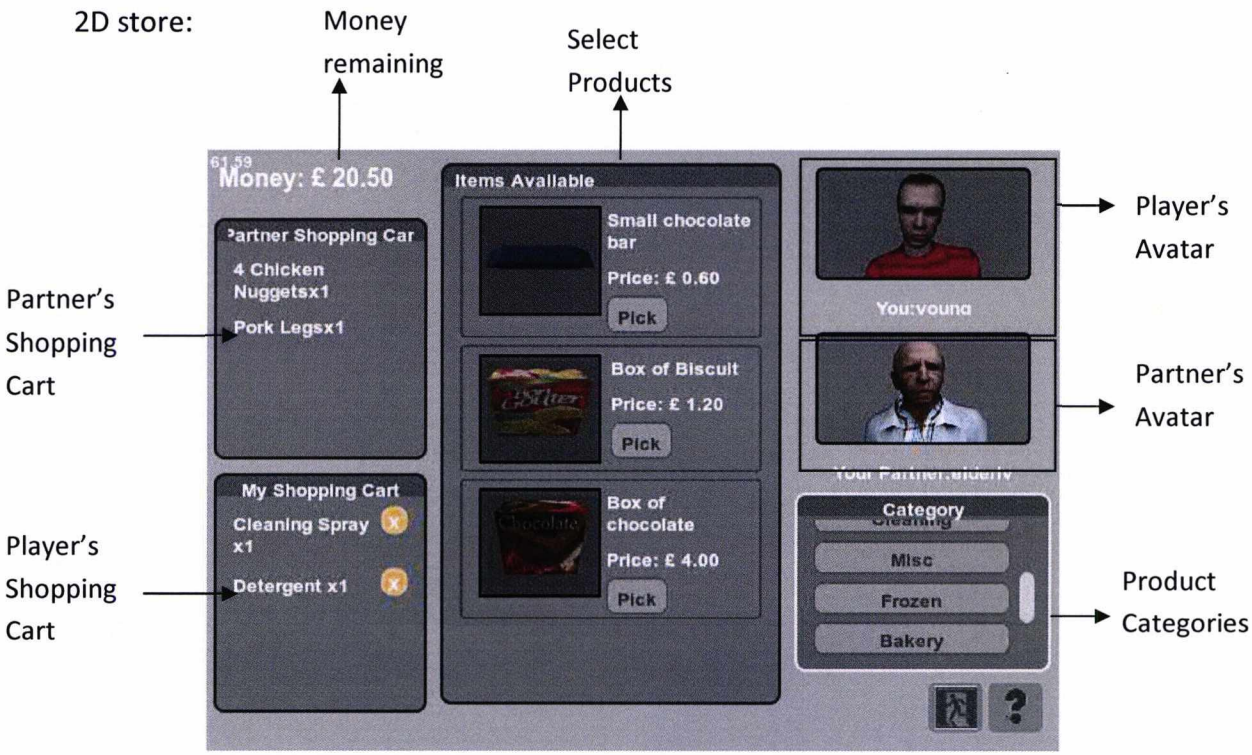
5.4 Final virtual world system

After incorporating the improvements from the third testing session, a further testing session was carried out with the virtual store system. No major problems were detected. Therefore, the environments in the third prototypes were used in the experiment studies (See Figure 24 for screenshots of the virtual environments used).

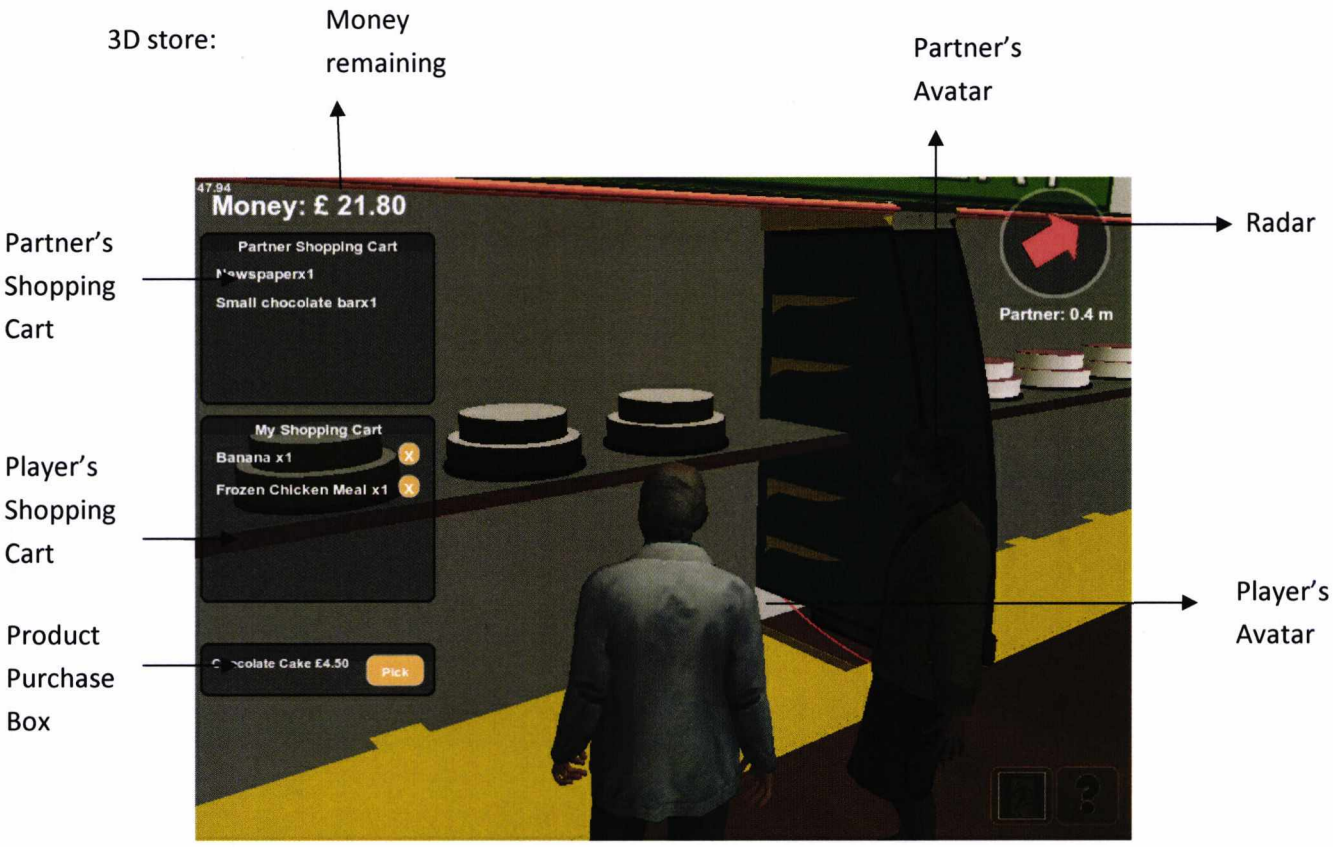
Virtual island system: 3D virtual island (text based chat)

Virtual store system: non 3D and 3D store (Voice based communication)

2D store:



3D store:



Avatar selection room:

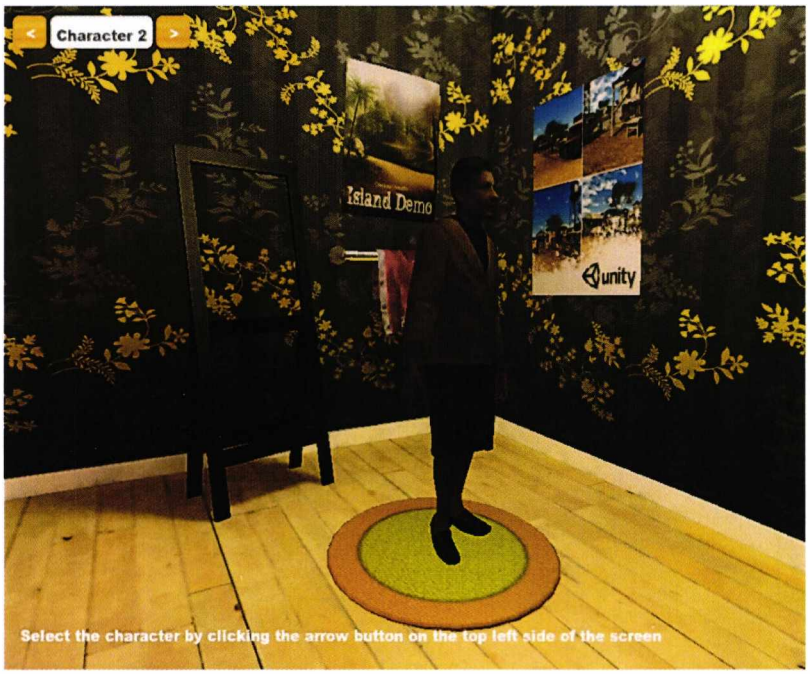


Figure 24: Screenshots of the virtual environments used in the studies in chapters 6 and 7

As voice communication had replaced text communication in the system used in the virtual store study, the hardware configuration for this system had also changed. The new

configuration is shown in Figure 25. The hardware configuration for the system used in the virtual island study remains the same as shown in Figure 21.

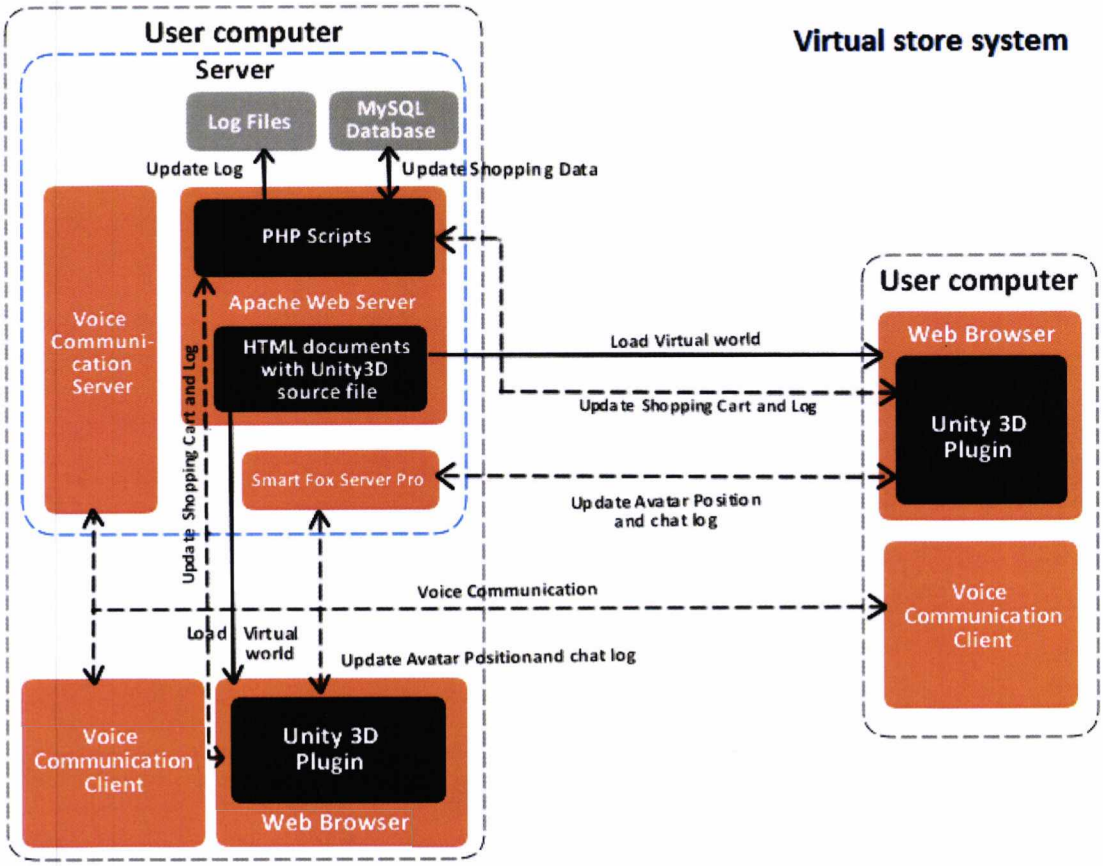


Figure 25: A summary of the hardware configuration for the virtual store system which used voice communciation

5.5 Key lessons learnt from the development process

A number of lessons had been learnt from the development process in this chapter. I found the focus group session to be particularly useful, giving a number of useful guidelines to select and design an appropriate virtual environment to carry out studies with older people. In fact, the virtual island design was based on one of the suggestions from the focus group which suggested using virtual worlds as a tool to survey tourist locations. In addition, the use of high fidelity older looking avatars in the virtual environments was also done in response to the negative reflections about the young and cartoon-shaped avatars that were identified during the focus group discussions.

In the evaluation process, the RITE method was also useful. This method allowed solutions to specific problems encountered by older users to be developed and tested out swiftly (For instance, when it was found that older people had difficulty locating their partner, an "arrow radar tool" was created etc). This method was especially useful in developing virtual environments for older people, as this method allowed improvements to be made without having to recruit a large number of older participants which could prove costly.

5.6 Experiment procedure

The virtual world systems developed in this chapter were then used to carry out the experiments to investigate how social interaction in virtual worlds could be improved for older people. Overall, the experiment was divided into two parts, a virtual island study where participants carried out a discussion task in a virtual island and a virtual store study where participants carried out a shopping task in the 2D and 3D virtual stores. Table 10 provides an overview of the characteristics of the two experiments. Exact details of the experiment procedure and the results of the virtual island study are shown in Section 6.3 and in Section 7.1 for the virtual store study.

Characteristic	Virtual island study	Virtual store study
Virtual environment	A 3D virtual island	a 2D and a 3D virtual store
Task	Generating ideas on what the island could be used for (Open-ended discussion task)	Discussing and agreeing on what goods to purchase for a birthday party/ picnic
Analysis	Comparison of age related differences	Determining the factors affecting social interaction experience, Qualitative interview data
Data collected	Questionnaire, Behavioural data	Questionnaire, Interview
Mode of communication	Text	Voice
Participants	30 older and 30 younger people	38 older people
Thesis Chapter	Chapter 6	Chapter 7

Table 10: An overview of the two experiments carried out using the virtual world system developed in this chapter

Dividing the study into two parts allows for richer data to be obtained. The idea generation task provided in the virtual island study is more open-ended, giving more freedom for users to explore the island and socialize. This allows for collection of behaviour data which more accurately reflect how users typically behave in virtual worlds. Due to the ease in accessing the virtual world and the simplicity of the task, the virtual island system was used to address the second research question, by carrying out studies with both older and younger users to investigate age related differences in user engagement in virtual worlds.

In comparison, the task provided in the virtual store study is more goal-oriented allowing users to focus more on the differences between the 3D and non 3D store. By allowing participants to use both stores in one session, participants could more easily determine how each factor in the 3D virtual world affects social interaction by comparing them with the elements from the non 3D store (3D vs 2D avatars for instance). This allows for richer data to be obtained when interviewing participants about their social experiences. Therefore, the virtual store system was used to carry out the study to address the third research question, to

determine the factors affecting social interaction experience for older people in virtual worlds.

Even though the virtual world systems developed in this chapter lack some of the functionalities found in commercial virtual world systems existing today, they contain the core functionalities which have persisted historically in virtual worlds. For instance, as discussed in section 2.3.1, factors such as using the avatar to mediate user interactions have remained persistent in virtual worlds, despite changes in how they are visualized (in text, 2D or 3D images). By using a simplified version of the virtual world in the experiment studies in chapters 6 and 7, we would be able to focus more on the interactions of older users with these core functionalities. This would allow the results to be more applicable to future generations of virtual worlds as well, as these core functionalities would likely continue to persist. Using a simplified virtual world system was also necessary as it was essential to develop a system that older users with little computer experience could learn and use in a short period of time to make the experiment studies feasible.

Even though a minority of older users currently engage with virtual worlds (The Second life Survey, 2007), (Pew Research Center, 2010a)), this number could increase in the future as virtual world technology continues to diffuse. Younger cohorts of older users (particularly those in the pre-senior (55-64 year) age range) who are already utilizing many types of computer technology (Pew Research Center, 2010a) would likely be those who adopt this technology and benefit from it as they grow older. Therefore, such users were also included in the experiment studies in chapters 6 and 7.

5.7 Conclusion and chapter implications

This chapter has described the process in which a virtual world system for carrying out experiment studies with older users was developed. A focus group study was first conducted to identify guidelines in designing an appropriate system for older people. Key concepts such as age appropriateness and high realism were identified. Unity3D and SmartFoxPro were then used to develop the virtual world system based on these concepts. Afterwards, the system was then iteratively tested and refined. The RITE method which was used in the testing of the system was particularly useful, allowing changes and improvements to be introduced and measured promptly.

The system developed here would allow experiments related to virtual environments to be carried out more easily with older people, in particular, those who are not familiar with technology and computers. The studies carried out in the later chapters (6 and 7) would make use of this system.

Chapter 6: Virtual island study to investigate age related differences between older and younger users in their use of virtual worlds for social interaction.

Using the virtual world system developed in the previous chapter, I carried out a virtual island study and virtual store study to investigate the social interaction experience of older people in 3D virtual worlds. While there have been a number of studies investigating various aspects of social interaction and social behaviour in virtual worlds ((Harris & al, 2009), (Nowak & Biocca, 2003), (Casanueva & Blake, 2001), (Garau, Slater, Vinayagamoorthy, Brogni, Steed, & Sasse, 2003)), these studies focus mainly on younger users. As such, we do not know how the findings and concepts identified from these previous studies relate to older users. Little is also known about whether and how the various factors of virtual worlds or of older users themselves influence social interaction experience. The two studies were carried out to address these questions.

This chapter presents the results from the virtual island study. The results from the virtual store study are presented in the next chapter. In the virtual island study, an age comparison approach is adopted (similar to the study in chapter 4). In particular, this chapter analyzes the age related differences between older and younger people on various aspects of user engagement in virtual worlds (quality of social interaction, non verbal social behaviour etc). More specifically, the objectives are to:

1. analyse age related differences in factors related to the quality of social interaction in a 3D virtual world and age related differences in the various factors related to interaction in a 3D virtual world (such as navigational ability, physical presence etc)

2. analyse age related differences in how the factors related to the characteristics of older users and the factors related to interaction in the virtual worlds (navigation, the avatar etc) relate to the quality of social interaction.

3. analyse age related differences in non-verbal social behaviours displayed by older and younger users.

Parts of the results from this study were published as an article in a special issue on presence and interaction at the Interacting with Computers Journal (Siriaraya & Ang, 2012b).

Next, I discuss the various factors used to measure the quality of social interaction and the factors thought to affect the social interaction experience of older people in 3D virtual worlds which were examined in the two studies.

6.1 Factors affecting the quality of social interaction for older users in 3D virtual environments

In the two studies, a number of factors were used to measure the quality of social interaction.

One measure frequently used by past studies which I have also adopted is social presence (or co-presence) (as described in section 2.6.1). A common goal in the design of technologies which mediate communication and collaboration has been to increase the level of social presence which users perceive during social interaction (see (Biocca, Harms, & Burgoon, 2003)). Therefore, social presence can be argued to be a useful indicator in the effectiveness of a technology in facilitating communication. Previous studies have shown that users are more satisfied with a virtual world if it provides them with a higher level of social presence (Jung, 2011). This factor has been used to measure the quality of communication in shared virtual environments in previous studies (such as (Garau, Slater, Vinayagamoorthy, Brogni, Steed, & Sasse, 2003) etc).

Other factors used to measure the quality of social interaction in the two studies were the perceived quality of the communication process and the perceived satisfaction in the outcome of the task. The former refers to how well users understood each other during communication and the later refers to (in the context of the two studies) the degree in which users were satisfied with their performance in carrying out the social interaction tasks given to them. Such measures have been commonly used in past studies to evaluate the effectiveness of a platform in carrying out social interaction tasks ((Vilhjálmsson, 2003), (Suh, 1999), (Simon, 2006)).

Based on previous studies, I speculate that a number of factors could affect the quality of social interaction of older people in 3D virtual worlds. These factors could be divided into 2 main groups, those related to the characteristics of older people themselves (user factors), and factors related to their engagement with the virtual worlds (platform factors).

6.1.1 User factors

Studies related to older people and technology have found that certain characteristics of older people could affect their use of technology (see section 2.4.2). Prior experience with technologies with similar functionalities as virtual worlds could be one factor which influences how well older people are able to use virtual worlds for social interaction. For instance, prior experience with 3D spatial environments could influence how well older people are able to carry out tasks in the virtual world (Moffat, Zondermana, & Resnicka, 2001). Internet experience has also been found to be related to how fast older users are able to carry out a navigation task in a 3D virtual environment (Sjolinder, Hook, Nilsson, & Andersson, 2005). As such, older people who have more experience with computer mediated communication software and 3D virtual environments could perform better in the 3D virtual worlds used in this study and thus have a higher quality of social interaction.

Another factor frequently investigated in studies related to older people and computer use is computer anxiety ((Ryu, Kim, & Lee, 2009), (Jung et al, 2010)). A number of studies have argued how this factor acts as a barrier to the acceptance of computer technology ((Phang, Sutanto, Kankanhalli, Li, Tan, & Teo, 2006), (Mallenius, Rossi, & Tuunainen, 2007)) and could influence computer related performance (Mahar, Henderson, & Deane, 1997). Therefore, I believe this factor might also affect how well older people are able to use virtual worlds in

social interaction and therefore their quality of social interaction.

The level of scepticism towards CMC technology might also influence a user's attitudes towards using virtual worlds for social interaction. One study showed that people who are more sceptical towards CMC are less motivated to develop online relationships and tend not to use Paralanguages such as emoticons[27] during social interaction in the virtual world (Utz, 2000). Older people in particular could hold negative perceptions towards online relationships and CMC technology. One study found that older people perceived the internet as not being a welcoming place for social interaction (Lehtinen, Nasanen, & Sarvas, 2009). Older people felt that online relationships were superficial and that the people who they meet online could not be trusted. A similar finding was also reported in older people's perceptions towards online communities. Non users felt that people who used online communities were those who had something to hide and felt that online communities were not real (Pfeil U. , 2009).

The cognitive and physical ability of older people might also affect how well they are able to use virtual worlds. Previous studies have shown how age related declines such as declines in spatial ability and declines in sensory and motor skills reduce older user's performance in a number of computer technologies (see section 2.4.2). Virtual worlds are relatively complex platforms (Pfeil, Ang, & Zaphiris, 2009) and often have multiple channels of interaction which can cause cognitive load problems for even young users (Ang, Zaphiris, & Mahmood, 2007). Thus, interaction in virtual worlds could depend considerably on these skills.

6.1.2 Platform factors

Various aspects of the virtual world could also affect the quality of social interaction for older users. Stanley et al (1998) suggested that factors such as the degree of presence and the ability to navigate could affect how well users are able to perform tasks in a 3D virtual world. Navigating in a 3D spatial environment in particular could be difficult for older people due to their reduced cognitive and physical abilities. Studies have shown how older people are able to perform navigation tasks less effectively than younger users (Sjolinder, Hook, Nilsson, & Andersson, 2005) (Sayers, 2004). Not being able to navigate effectively could influence social interaction experience in 3D spatial environments. Those unable to navigate well could have less control over the spatial information they receive (for instance, they might have difficulty finding their partner's avatar when socializing). Also, many of the non verbal social behaviours (interpersonal distance etc) and social conventions rely on users being able to navigate their avatars to a certain position ((Becker & Mark, 2002), (Smith, Farnham, & Steven, 2002)). The inability to move around freely in the 3D virtual environment could result in users not being able to utilize such behaviours and could thus lower their quality of social interaction.

Physical presence is another important aspect in a user's engagement with virtual worlds (as described in section 2.6.1). Factors such as having objects with high visual realism,

[27] A method of using ASCII characters to express emotions, usually found in text based communication (for instance ":)" could indicate a smiley face)

contingency between user action and their interactions and a high level of system interactivity could result in a higher level of physical presence for users (IJsselsteijn, Ridder, Freeman, & Avons, 2000), (Lombard & Ditton, 1997). Studies have suggested that the level of physical presence can affect a user's enjoyment in virtual environments (see (Lombard & Ditton, 1997)). Users are more inclined to continue to use virtual worlds and are more satisfied with their experience if they perceive a higher level of physical presence (Jung, 2011). As such, the two studies also examined the relationship between physical presence and the quality of social interaction for older users.

Apart from this, the visual representation of the users in the virtual worlds or what is known as "avatars" could also influence a user's social interaction experience. Studies have found that certain characteristics of the avatars (such as avatar realism and anthropomorphism etc) influence the level of social presence and the quality of communication that are perceived by users (Nowak & Biocca, 2003), (Casanueva & Blake, 2001). Studies have also suggested that older people have preferences for certain types of avatars (Cheong, Jung, & Theng, 2011), (Morandell, Hochgatterer, Fagel, & Wassertheurer, 2008) . Therefore, the experiments I carried out would also investigate the impact of the avatars on the quality of social interaction.

6.2 Non-verbal social behaviour

Apart from investigating age related differences in the factors related to social interaction, I also investigated the non-verbal social behaviours which users displayed. Such behaviours could be an important aspect in a user's social interaction experience in 3D virtual worlds. For instance, certain social conventions in virtual worlds make use of these behaviours (one example is how users move their avatars close to their partner to signal the beginning of a conversation) (Becker & Mark, 2002). Non verbal social behaviours could also influence the level of social presence perceived by users. For instance, users reported a higher level of social presence when socially interacting with a partner who was represented by a high realism avatar whose eye gaze was controlled to look at the participant when communicating, compared to those who looked around randomly (Garau, Slater, Vinayagamoorthy, Brogni, Steed, & Sasse, 2003).

One particular non-verbal social behaviour which has received wide attention in virtual world research is proxemics, or the interpersonal distance between a user's avatars. Smith et al (2002) found that users in a 2D chat space often tried to position their avatars close to their partner and tried to turn their avatars to face their partner when talking to each other as if they were communicating in the physical world. A similar pattern of behaviour has also been observed in 3D virtual worlds. Researchers such as Yee et al (2007) argue that most social conventions regarding interpersonal distance and mutual gaze in the physical world can also be found in the virtual world. Friedman et al (2007) further showed that these spatial behaviours were not entirely identical but were transformed as a result of the technical constraints of virtual world (such as in vision and perception). These studies highlight the

importance of interpersonal distance and avatar gaze to social interaction in virtual worlds. Therefore, in investigating non verbal social behaviours, I will focus on these two behaviours.

6.3 Study Design

In the virtual island experiment, 60 participants (15 pairs of older people and 15 pairs of younger people) were asked to carry out a social interaction task with each other in the virtual world. This study used the two virtual environments developed in the previous chapter, namely the virtual island and the avatar selection room (section 5.4). Participants were given a choice of five avatars to choose from. This includes an older and younger male, an older and younger female and a non human avatar. The non human avatar was included to investigate the effect of anthropomorphism (the degree to which objects (in this case, avatars) are perceived to resemble human-beings) on the social interaction experience of older people. This factor has been found in past studies to influence a user's sense of presence (Nowak & Biocca, 2003) and the perception of their partners (such as their credibility) (Nowak & Rauh, 2006).

6.3.1 Study Procedure

Participants were recruited by snowball sampling, a sampling method in which participants who had already participated in the study earlier on were asked to identify new potential participants (Heiman, 2001). This sampling method was used because of the difficulty in identifying older users who were receptive to the idea of using 3D virtual worlds and had access to computers able to run the virtual environments used in the study. In fact, some sessions had to be abandoned due to low performing computers. The snowball sampling method was also used to recruit younger people as well to ensure consistency in the sampling process. Older people aged 55 and above and younger people in their 20's and early 30's were recruited for the study.

After recruitment, a pair of participants was asked to enter the study's website at a time of their convenience. Both participants started by visiting a webpage which helped them install the Unity3D-plugin and offered information about the purpose and procedure of the study (screenshot shown in Figure 26). Then, participants were directed to a registration page (screenshot shown in Figure 26) where they were asked to provide basic information about themselves (such as their gender and date of birth, etc) and choose an avatar (from the avatar selection module embedded in the registration page). Afterwards, they were brought to the pre-questionnaire page and asked to fill in the pre-questionnaire. Participants were then redirected to an introduction page that provided basic instructions on how to use the virtual world (e.g. how to navigate, send text messages, how to use the "radar tool"). After this, the two participants entered the virtual island together and carried out the social interaction task (screenshot shown in Figure 26). If one participant arrived at this page earlier then their partner they had to wait for the other participant to arrive before being allowed to enter the virtual island.

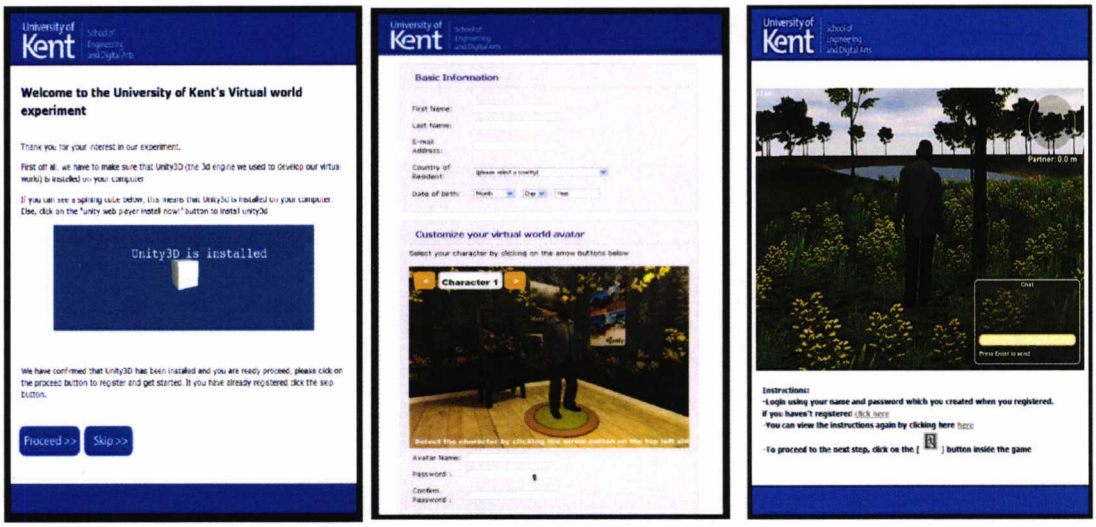


Figure 26: A screenshot of the introduction page (left) and the avatar registration page (middle) and the virtual island (right)

Participants were asked to carry out a social interaction task with each other in the virtual island. As the main focus of this experiment was to investigate social interaction, giving a task was necessary to encourage participants to communicate with each other. Without having a task, participants might not participate in social activities in a meaningful way and this would limit the validity of the results. For the task, participants were given a scenario in which they and their partner had won a virtual island from a competition. Participants were asked to explore the island and discuss and come up with ideas on what they would like to do with the island. The specific instructions given to the participants were:

"You and your partner have won first prize in a competition and have been given ownership of a small island in the middle of the ocean. Both of you have decided to visit this island to see what it has to offer.

Look around this island and decide with your partner what to do with it. You and your partner may use this island for any purpose you wish and all the costs would be covered by the organizers of the competition.

You can see the instructions on this page again by clicking on the help button (the one with the question mark). After you have finished the discussion with your partner, click on the exit button to proceed to the questionnaire and end this task."

The task was designed to provide the participants with a certain degree of freedom to explore the virtual island, but also required them to communicate with their partner. A screenshot of the whole virtual island could be found in Figure 27. Participants left the island after they and their partner have agreed on what they intend to do with the island. After completing the task, participants were taken to a page with the post-questionnaire. A complete list of the screenshots of the web pages used in the virtual island study is shown in Appendix C.

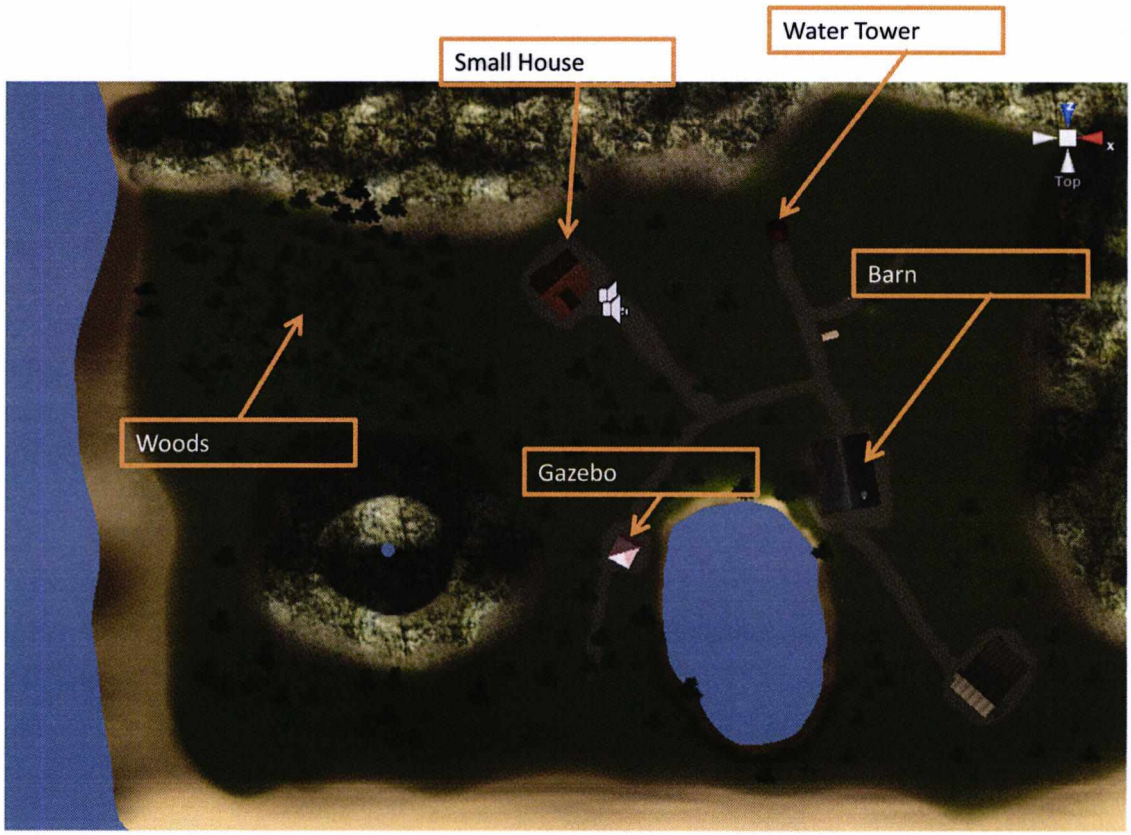


Figure 27: A screenshot of the top-view of the virtual island as shown in the Unity3D editor

6.3.2 Data collection

Data was collected from two main sources. From questionnaires and from user behaviour data which was logged automatically by the virtual world system. The questionnaires were used to examine the factors discussed in section 6.1. The user behaviour data was used to examine age related differences in the display of interpersonal distance and mutual gaze.

6.3.2.1 Questionnaire

Two questionnaires, a pre-questionnaire (administered before the users visited the virtual island) and a post-questionnaire (administered after the users visited the virtual island) were administered to the participants. The pre-questionnaire was used to gather information about the general demographics and characteristics of the participants (age, gender, experience with computers, computer anxiety etc.) and the post-questionnaire was used to examine the experience of participants after using the virtual island (See Appendix E for the questionnaires used in the study). In the following section, I outline the key measures used in the two questionnaires.

The quality of social interaction was evaluated from the following four measures

a) *Social presence:* In this study, social presence was measured using two criteria. The first was related to the degree in which users perceive themselves as being in the environment with another person. Questions were based on Slater (2000). The second criterion was related to the extent in which users perceived their social experience in the virtual environment as being similar to a face-to-face social interaction. Questions related to this criterion were based on Nowak & Biocca (2003).

b) *Perceived quality of communication:* The quality of communication was measured by how well participants felt they were able communicate with their partner, how well they understood their partner and the sense of control participants had over the conversation. Questions investigating the quality of the communication were adapted from (Vilhjálmsson, 2003).

c) *Perceived task performance*: This measure was related the how well participants felt they performed on the communication task and how satisfied they felt with the outcome. Questions were also adapted from (Vilhjálmsson, 2003).

d) Overall satisfaction with social experience: Participants were asked to rate how satisfied they were with their social experience on a scale of 1 to 5.

Although, many of these measures are similar to each other, they each represent a different aspect of social interaction in 3D virtual worlds. Social presence is related mostly to the degree that users perceive their partners to be present with them and the degree that they perceive social interaction in the virtual world to be similar to the physical world. The quality of communication focuses on the message (or content) in social interaction, evaluating how well users are able to understand each other through the platform. Task performance evaluates how well participants felt they performed on the social interaction task. This measure would be of particular interest to those looking to design virtual environments to carry out a specific social task (such as to facilitate certain computer-supported cooperative work). A single scale item was also used to measure the user's overall satisfaction with their social experience. This represents how satisfied participants felt with their overall social experience in the virtual world. The limitations on using single scale items are discussed in the section 6.6.

In addition, participants were also asked to rate how much they enjoyed their experience in the 3D virtual world on a scale of 1 to 5.

The second part of the questionnaire consisted of several factors which are believed to be linked to the quality of social interaction for older people in virtual worlds.

1. *User factors:*

    a. *Past experience with computer technology*: Participants were asked about their prior experience with computer technology in 5 areas: i)Computers ii) the internet iii)E-mail iv) Text messaging programs and v) 3D games. The questions used were adapted from Sjolinder et al's study (2005). Two further experience categories, E-mail and Text messaging programs were added (Sjolinder's study only measured prior experience with computers, the internet and 3D environments) to investigate the effect of participant's familiarity with asynchronous and synchronous text base communication programs. Participants were asked to rate the frequency and duration which they had used each of the technologies.

    b. *Scepticism of using CMC technology to communicate:* The Scale used was adapted from the study examining the development of friendships in virtual worlds conducted by Utz (2000).

    c. *Anxiety in relation to the use of computer technology:* This variable measures the level of anxiety when it comes to using computer technology. Questions were adapted from Lee's study (Ryu, Kim, & Lee, 2009).

    d. *Health*: Although, specific declines in cognitive and physical abilities were not measured, I measured the general physical condition of users instead. The rationale behind this being that older people who have difficulties in performing activities in everyday life would likely have suffered from declines in their physical and cognitive abilities (Ryu, Kim, & Lee, 2009). Questions from Ryu et al's study (2009) were used.

    In addition, other demographic variables, such as gender, age and the level of previous acquaintance between users and their partner were also collected (participants were asked to rate how well they knew their partner on a scale of 1 to 5)

2. *Platform factors:*

    a. *Physical presence*: The Slater-Usoh-Steed questionnaire was used to measure physical presence in this study (Slater, Steed, & Usoh, 1994) .

    b. *Avatar:* Questions were designed to measure how much the avatars impacted the user's interaction in the virtual environment. The questions from Vilhjálmsson's study (2003) were used.

c. *Navigational ability:* The questions in this measure were based on the task based taxonomy of navigation proposed by Tan et al (2001). According to this taxonomy, navigational tasks could be divided into three subtasks which are exploration, searching and inspecting. In the context of this study, this refers to the degree in which users were able to explore what was available in the island (exploring), the ease in which users were able to find a particular object (searching) and the degree in which participants were able to gather details about a particular object (inspecting).

6.3.2.2 User behaviour data

The location (in the form of Cartesian coordinates (x,y,z)) and the orientation (the yaw angle) of the user's avatar was logged automatically every second by the virtual world system. This data was used to analyze interpersonal distance and gaze angle, using a method similar to previous studies (Smith, Farnham, & Steven, 2002) (Yee, Bailenson, Urbanek, Chang, & Merget, 2007). Interpersonal distance was calculated from the two dimensional distance between the two user's avatar. (The area accessible to the participants in the 3D island contained no significant elevation, so the height distance was discounted).

As users communicated with their partner (i.e. sent a text message) the system also logged the user's gaze angle. Gaze angle in this study refers to how much a user tries to faces their avatar towards their partner's avatar when communicating. An angle of zero would indicate that the avatar is directly facing their partner when sending the text messaging and an angle of 180 would indicate that they are facing the opposite direction. Gaze angle was calculated from the orientation and location of the user's avatar and their partner's location.

6.4 Findings and results

Reliability tests showed good statistical reliability on the multi-item measures used in this study, except for two variables: Scepticism of using CMC technology to communicate and the value of the avatar. Table 11 shows the Cronbach's alpha value on each measure.

Measure	**Cronbach's alpha**
Social presence	0.76
Quality of Communication	0.71
Perceived task performance	0.85
Scepticism	**0.25**
Anxiety	0.85
Health	0.82
Physical presence	0.81
Navigation	0.86
Avatar	**0.63**

Table 11: The statistical reliability of the measures used in the questionnaire in the virtual island study

A Cronbach's alpha value of more than 0.7 indicates good statistical reliability (Field, 2005). As skepticism had an extremely low value, this measure was removed from the analysis in this study. The Avatar measure also had a relatively low statistical reliability, but was still retained in the analysis in this study (see section 6.6 for a discussion).

6.4.1 Participant demographics

Table 12 provides a summary of the demographics and characteristics of the participants.

Variables			**Older people**	**Younger people**
Demographics	Gender	M	9	13
		F	21	17
	Age		Mean=62.93 Min=55, Max=80 (SD=6.39)	Mean= 25.76 Min=22, Max=33 (SD=2.61)
User factors	Computer experience (score out of 10)		Mean =7.60 (SD=1.91)	Mean=9.60 (SD=0.56)
	Internet experience (score out of 10)		Mean =7.17 (SD=1.98)	Mean=9.37 (SD=0.77)
	Email experience (score out of 10)		Mean =7.17 (SD=1.68)	Mean= 9.47 (SD=0.97)
	Text-based communication program experience (score out of 10)		Mean =3.83 (SD=2.32)	Mean=8.53 (SD=1.66)
	3D game experience (score out of 10)		Mean =2.23 (SD=0.68)	Mean=5.57 (SD=2.19)
	Anxiety (score out of 5)		Mean =2.18 (SD=0.95)	Mean=1.52 (SD=0.69)
	Health (score out of 5)		Mean =1.86 (SD=0.80)	Mean=1.31 (SD=0.55)
	Level of Acquaintance (score out of 5)		Mean=4.0 (SD=1.19)	Mean=3.7 (SD=1.15)

Table 12: A summary of the participants' demographics in the virtual island study

Overall, older people who participated in the study had relatively high experience with computers, the Internet and e-mail, but had little experience with text-based communication and 3D programs. In comparison, younger people were very familiar with computers, the Internet, e-mails and text-based communication programs and were moderately familiar with 3D games.

In regards to computer anxiety, t-tests show that older people had significantly higher levels of computer anxiety than younger users, which was expected ($t(58) = -3.05$, $p < 0.01$).

Also not surprisingly, older people had significantly more difficulties in regards to their health than younger users ($t(58)= -3.08$, $p<0.01$). However, the level of computer anxiety and health problems of the older participants in this study could be considered to be quite low (both were lower than half). Both older and younger participants in the study also had relatively high levels of acquaintance with their partners. T-tests showed that there was not a significant difference in the level of acquaintance between users in the two age groups.

6.4.2 Avatar selection

As previously mentioned, participants were given a choice of five avatars to represent themselves in the task. Table 13 shows a summary of the types of avatars selected by the participants.

	Older participants			Younger participants		
	Male	Female	Total	Male	Female	Total
Old Male	55.6%	0.0%	16.7%	15.4%	11.8%	13.3%
Old Female	0.0%	28.8%	20.0%	0.0%	5.9%	3.3%
Young Male	11.1%	0.0%	3.3%	15.4%	0.0%	6.7%
Young Female	0.0%	57.1%	40.0%	7.7%	23.5%	16.7%
Non-Human	33.3%	14.3%	20.0%	61.5%	58.8%	60.0%

Table 13: A summary of the types of avatars selected by participants in the virtual island study grouped by gender and age

Previous studies have found that users were more likely to choose avatars that were more human-like and had the same gender as themselves (Nowak & Rauh, 2006). However, in this study, more than half of the younger and 20% of older users selected non-human avatars. Nowak (2006) further suggested that avatar selection might be context specific. Ducheneaut et al's (2009) study also found evidence to supported this notion as they found that compared to users of social-oriented virtual worlds (such as Second life), more users of gaming virtual worlds (such as World of Warcraft) preferred avatars which were different from themselves (Ducheneaut, Wen, Yee, & Wadley, 2009). This study shows a similar result as a considerable number of younger users seem comfortable in using non-human avatars in their interaction with the virtual island which they perceive to be similar to a game. The avatar selections of older users are discussed in more detail in section 7.2.2.

6.4.3 Age differences in the quality of social interaction and user engagement in virtual worlds

As mentioned in section 6.3.2.1, the quality of social interaction was measured by social presence, the quality of communication, perceived task performance and overall satisfaction in social experience. Table 14 summaries the age differences between these measures.

Variable	Older people	Younger people	Significance
Social presence	Mean=3.13 (SD=0.80)	Mean=3.52 (SD=0.63)	**Significant, t(58) = 2.1 ,p < 0.05**
Quality of communication	Mean=3.90 (SD=0.681)	Mean=3.94 (SD=0.63)	Not significant t(58)=0.25 ,p=0.81
Perceived task performance	Mean=3.58 (SD=1.10)	Mean=4.00 (SD=0.81)	Not significant t(58)=1.64,p=0.11
Overall satisfaction with social experience	Mean=3.33 (SD=1.24)	Mean=3.53 (SD=0.97)	Not significant t(58)=0.70,p=0.49

Table 14: A summary of the age differences in the measures evaluating the quality of social interaction in the virtual island study

As seen in Table 14, younger people perceived a higher level of social presence than older people. However, the difference in the quality of communication, task performance and overall satisfaction with social experience between older and younger users was not significant.

Next, the age related differences in the perception of physical presence, navigation and the importance of the avatar were examined. The results are shown in Table 15.

Variable	Older people	Younger people	Significance
Physical presence	Mean=2.81 (SD=1.02)	Mean=3.10 (SD=1.03)	Not significant t(58)=1.05 , *p=0.3*
Navigation	Mean=3.29 (SD=0.83)	Mean=3.82 (SD=0.84)	**Significant, t(58)=2.46,p<0.05**
Avatar	Mean=3.41 (SD=0.77)	Mean=3.37 (SD=0.88)	Not significant t(58)=-0.21,p=0.84

Table 15: A summary of the age differences in the measures evaluating the importance of the avatar, physical presence and navigation in the virtual island study

T-tests showed that there was no significant difference in the perception of physical presence and the importance of the avatar between older and younger people. In regards to navigation, younger people found it significantly easier to navigate in the virtual world than older people. This result was consistent with other studies. For instance, one study looking into the ability of older people in finding items in a virtual supermarket found that younger people performed more effectively than older people and that older people reported more difficulty in navigation than younger users (Sjolinder, Hook, Nilsson, & Andersson, 2005).

Even though there was no significant age difference in the overall importance of the avatars, certain avatar choices seem to affect the quality of social interaction for older participants. T-tests showed that when their partners used the non-human avatar, older users reported being less satisfied with their overall social experience, t(28)=2.88 ,p<0.01 (mean=2.17 for non human avatars and mean=3.63 for human avatars) than those whose partners used the human avatars.

T-tests were also carried out to investigate age related differences in regard to user enjoyment. Although older people on average enjoyed their experience less in the 3D virtual environment (Mean=3.53, SD=1.14) than younger people (Mean=3.87, SD=1.11), this difference was not significant (t(58) =1.15, p=0.25).

6.4.4 Relationship between user and platform factors and the quality of social interaction measures

Pearson's correlation tests were conducted to explore the relationship between the measures for the quality of social interaction and the user and platform factors (physical presence navigation and the avatar). A summary of the results is shown on Table 16.

		TEXT	GAM	ANX	ACQ	PRE	NAV	AVA
SP	Older	**0.49****	0.02 (p=0.98)	-0.02 (p=0.92)	**0.37***	**0.64****	**0.50***	0.31 (p=0.10)
	Younger	0.21 (p=0.26)	**0.43***	-0.24 (p=0.20)	-0.18 (p=0.33)	**0.4***	-0.05 (p=0.78)	**0.38***
QOC	Older	0.27 (p=0.15)	0.15 (p=0.44)	**-0.40***	**0.49****	0.29 (p=0.13)	0.33 (p=0.07)	0.18 (p=0.36)
	Younger	0.15 (p=0.42)	0.35 (p=0.06)	-0.18 (p=0.35)	-0.36 (p=0.053)	0.31 (p=0.10)	0.05 (p=0.79)	0.31 (p=0.09)
PER	Older	0.27 (p=0.16)	0.08 (p=0.68)	-0.03 (p=0.86)	**0.46***	**0.47****	**0.42***	**0.58****
	Younger	0.04 (p=0.82)	**0.36***	-0.20 (p=0.29)	-0.01 (p=0.97)	0.34 (p=0.07)	0.06 (p=0.77)	**0.45***
SAT	Older	0.18 (p=0.35)	-0.14 (p=0.47)	0.28 (p=0.13)	0.32 (p=0.09)	**0.64****	**0.48****	**0.49****
	Younger	0.31 (p=0.10)	0.32 (p=0.08)	-0.22 (p=0.24)	-0.10 (p=0.60)	**0.58****	0.08 (p=0.68)	**0.50****

** indicates that correlation is significant at the 0.01 level (2 tail), * indicates that correlation is significant at the 0.05 level (2 tail)

Note: Computer, internet, E-mail and health were not shown as they had no significant correlations towards the measures for the quality of social interaction; Abbreviations: (SP=social presence, QOC= quality of communication, PER=Performance, SAT=satisfaction with social experience, TEXT= text messaging experience, GAME=game experience, ANX=computer anxiety, ACQ= level of acquaintance, PRE=physical presence, NAV=navigation and AVA=avatar)

Table 16: A table summarizing the factors which correlate (Pearson's correlation 2-tailed) with the factors measuring the quality of social interaction for older and younger people in the virtual island study. Only variables with significant results are shown.

Overall, the results were interesting in that different factors were related to the measures for the quality of social interaction for older and younger users. For older users, navigation

seemed to be an important factor, correlating with overall satisfaction in their social experience and with social presence. For users of both age groups, physical presence was also found to be related to most of the measures used for the quality of social interaction (such as social presence, performance and overall satisfaction in the social experience). Further correlation tests were carried out to determine what factors influence the perception of physical presence for older people. Experience with text messaging tools ($r(30)=0.38, p<0.05$), level of acquaintance ($r(30)=0.394, p<0.05$), the ability to navigate ($r(30)=0.648, p<0.001$) and the avatar ($r(30)=0.45, p<0.05$) correlated significantly with the perception of physical presence. None of these user factors except the avatar ($r(30)=0.62, p<0.001$) significantly correlated to the perception of physical presence for younger people.

In addition, I also examined how the user and platform factors relate to enjoyment for older and younger users. For older users, physical presence ($r(30)=0.625, p<0.001$), navigation ($r(30)=0.38, p<0.05$) and the avatar ($r(30)=0.386, p<0.05$) were related to enjoyment. For younger users, physical presence ($r(30)=0.405, p<0.05$) and the avatar ($r(30)=0.488, p<0.01$) was found to be related to enjoyment.

In regards to prior experience, it was interesting that for older people, experience with text messaging tools correlated with the perception of social and physical presence. Interestingly, this seems to be not the case for younger people. For younger users, only prior experience with 3D games correlated significantly with the perception of social presence. Another factor which correlated significantly with the measures for the quality of social interaction for older people (social presence, quality of communication and performance) was the level of acquaintance with their partners. This factor did not seem to be related for younger people. This might suggest that older people are more comfortable in using such tools to communicate with someone they are previously well acquainted with.

The avatar was also found to be related to two of the measures for the quality of social interaction for older people. The avatar had a moderate correlation with perceived performance, overall satisfaction in social experience and physical presence. For younger people, the avatar was also found to be related to perceived performance and overall satisfaction in social experience. However this factor was found to be related to social presence instead of physical presence for younger people.

As for the other user factors which were investigated, computer anxiety was found to be related to the quality of communication for older users. The measure for the general health in the meanwhile was not found to be significantly related to any of the measures for the quality of social interaction used in this study.

6.4.5 Age differences in the patterns of non-verbal social behaviour

6.4.5.1 Interpersonal distance

According to Hall (1966), there are 4 main zones of interpersonal distance: intimate distance zone (0-0.45m), personal distance zone (0.45-1.2m), social distance zone (1.2 -3.6m) and public distance zone (3.6m or more). Using the information about the users' position logged automatically by the virtual world system, I calculated the percentage of the overall amount of time each pair of users spent in each distance zone. Unity3D game distance was converted to physical world meters (in the virtual world used in this study, 1 game unit was about 0.236 meters). Figure 28 shows the distances as seen by the participants.

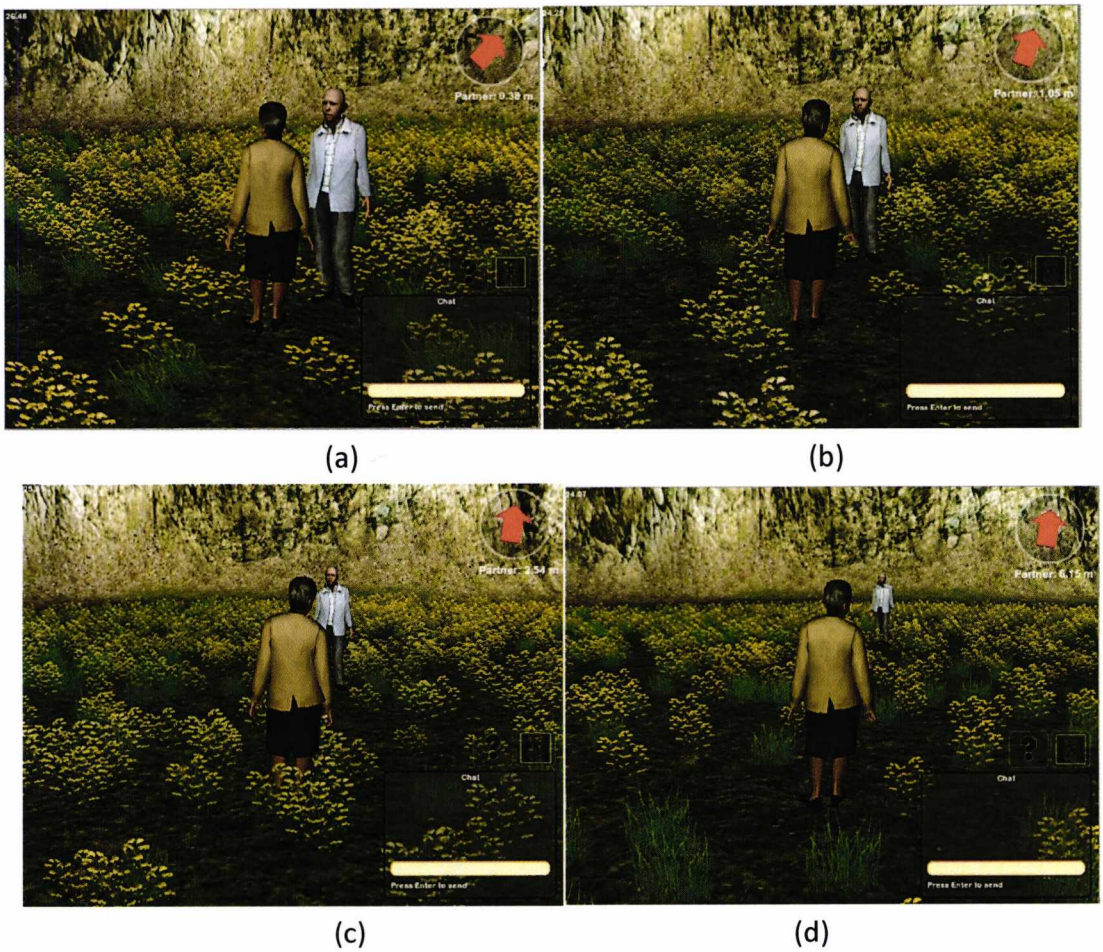


Figure 28: the four zones as seen from the virtual world system: Intimate (a), personal (b), social (c) and public (d) distances

A summary of the results is shown in Figure 29. T-tests showed that the difference in the percentage of time spent in the each zone between the two age groups was not statistically significant.

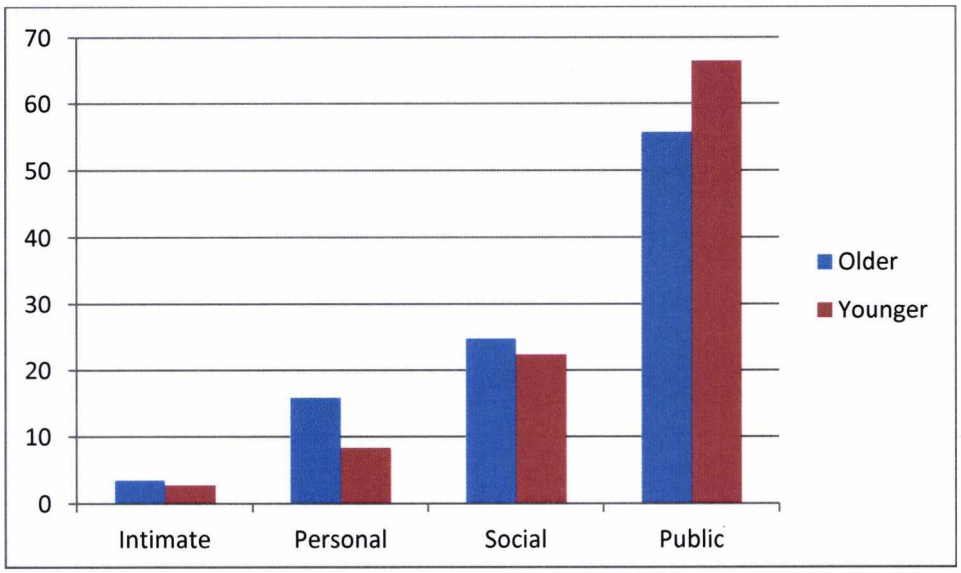


Figure 29: The average percentage of the time spent in each interpersonal zone.

When participants send messages to their partner, the virtual world system logged the distance between the avatar of the user who sent the message and their partner's avatar. I then used this data to calculate the average percentage of messages sent within each zone by each pair of users. This gave some interesting results, as shown in Figure 30.

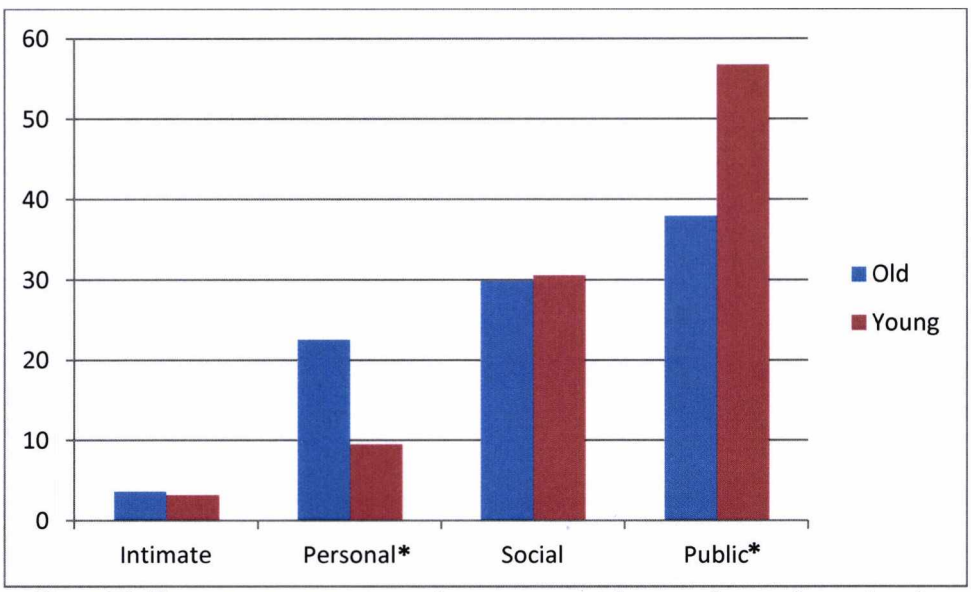


Figure 30: The average percentage of messages sent from each zone for each pair. Significant results are marked by asterisks

T-tests showed that older pairs exchanged more messages in the personal zones than younger pairs ($t(28)=-3.02, p<0.001$) and younger pairs exchanged more messages in the public zones than older pairs ($t(28)= 2.12, p<0.05$).

According to Hall, in social interaction in the public zone, very little verbal (such as voice tones) and non verbal cues (facial expressions etc) remain (Hall, 1966). Most communication

in this zone would be one way (such as a public speaker speaking to audiences) and users would need to either shout or use a voice amplifying device to communicate effectively. As social interaction in this study consists of mainly "pairwise social interaction", messages exchanged in the public zones would be unnatural and in the physical world we would expect most messages to be sent within the social, personal or intimate zones in a pairwise communication setting. Therefore, I grouped the messages into two categories: i) messages sent within the zones of "natural" pairwise interaction (i.e. from closer than the public zone) and ii) messages sent from the public zone.

A clear difference was found for users in the two age groups. Only 33% of younger pairs sent the majority of the messages from inside the "natural pairwise interaction zone" compared to 66% of the older pairs. T-tests also showed that older users who sent more than half of their messages inside this zone, reported a higher level of physical presence (Mean=3.07) compared to those who did not (Mean=2.30), $t(28)=2.19$, $p<0.05$. Apart from this, they also reported a higher level of satisfaction in their social experience (Mean=3.70 compared to 2.60), $t(28)=2.56$, $p< 0.05$. Social presence, however, was not found to be significant ($t(28)=1.71$, $p=0.10$). For younger people t-tests showed that the difference between these factors for users who sent messages inside and outside the "natural pair wise interaction zone" was not significant.

6.4.5.2 Gaze angle

Apart from logging the distance between the avatars when participants were communicating, the gaze angle of the interacting avatars was also logged. Similar to the distance between the avatars, I calculated the difference in the average gaze angle of older and younger pairs while they were exchanging messages. T-tests showed that there was no significant difference in the gaze angle between the two age groups.

The selection of non-human avatars appeared to have an impact on non-verbal social behaviour for older users. When looking at each individual user, I found that older users tended to have a larger average gaze angle when chatting with partners represented by non-human avatar (Mean=85.16 for non-human avatars and Mean=69.10 for human avatars), $t(28)=-2.454$, $p<0.05$, indicating that there was less of an attempt to orient their own avatars to face their partner's avatars when communicating. Participants also exhibited a larger average overall interpersonal distance when inside the virtual island if their partner used a non-human avatar (mean=33.27 meters for partners with non-human avatars and mean=17.01 meters for partners with human avatars), $t(28)=-3.14$, $p<0.05$. The difference in interpersonal distance when chatting was not significant however. In addition, this difference was only found among older users. For younger people, the average difference in the gaze angle and interpersonal distance was found not to be significant between partners using non-human and human avatars.

Altogether, it seems that when communicating, more older people had a tendency to exhibit proxemic behaviour in the virtual world which mimicked those in the physical world, when

compared to younger people. Unlike the physical world, where human senses restrict natural communication to a certain distance, the virtual world in this study allowed text messages to be sent instantaneously to their partners irrespective of the location of the avatars. Younger people seemed to take advantage of this as more than two thirds of the younger pairs sent more than half of their messages outside the "natural social zone". This was similar to the results of other studies which found a significant number of users communicating beyond the social zone (Friedman, Steed, & Slater, 2007) in a virtual setting. For older users however, on average, less than 40% of their messages were sent from outside the social zones. Older people who communicated mainly within this zone also reported higher levels of physical presence and overall satisfaction in their social experience.

6.4.5.3 Communication logs content

The messages that the participants sent to their partners as they carried out the task were also logged. On average, each pair spent 30 minutes on the task. Older participants on average submitted 29.6 messages (SD=19.32) and used 144.6 words (SD= 99.7). Younger participants meanwhile submitted 43.03 messages (SD=20.00) and used 164.23 words (SD=109.78). As for the content, participants often started by greeting each other in the virtual island. They also often communicated to co-ordinate their exploration (for instance, asking about where to go next or telling participants to follow them) or give tips for navigation (for instance, telling participants how to reach the lake or how to get to their current location etc). Other messages frequently exchanged were those used to direct their partner's attention to an object or to inform participants of what they had found in the virtual world (for instance, telling their partner that there is a pond at a certain location). Emoticons (the use of text characters to express emotions) were also frequently used by the younger participants (9 younger participants used emoticons while older participants did not). In regards to the task, participants generally came up with a diverse range of ideas, including building a resort for tourists, a conservatory for animals, a school, a honeymoon house for themselves or an agricultural plantation.

6.5 Conclusion and chapter implications

This chapter reports the findings from a virtual island experiment study which was carried out with 60 users (30 young and 30 old users). Participants were asked to carry out a social interaction task in a 3D virtual island developed in the previous chapter. The objectives of this study were to analyze age related differences in the quality of social interaction, the interaction with different aspects of the virtual world (navigation, physical presence and the avatar) and the display of non- verbal social behaviour. Another aim was to analyze whether there were any differences in how these aspects relate to the quality of the social interaction.

The following key findings were discovered:

1) Overall, older users reported significantly lower levels of social presence than younger users and significantly greater difficulty in navigation. In addition, older people found it more difficult to navigate in the 3D virtual world than younger users.

2) Different factors correlated with the measures for the quality of social interaction for the two age groups. For older users, navigational ability, level of acquaintance and previous experience with text messaging programs correlated to many of the measures. For younger users, prior experience with 3D games correlated significantly with social presence and perceived task performance. For both age groups, physical presence correlated with social presence and overall satisfaction in the social experience.

3) A comparison of non-verbal social behaviour between older and younger users showed that older users tended to exhibit proxemic behaviour in the virtual world which is more similar to the physical world.

4) The selection of non-human avatars seemed to have an impact on social interaction for older people. Older participants who had partners using a non-human avatar reported a lower level of satisfaction in their overall social experience. They also tended to maintain larger interpersonal distance during the study and not orient their avatars to face their partner's avatar when communicating. However, these results should be interpreted with caution, due to the low number of samples.

The main contribution of this study was in investigating the use of virtual worlds for social interaction by older people. In particular, this study examines whether there are age related differences in the quality of social interaction and in factors such as navigation and physical presence. Even though such factors (physical presence etc) have been investigated before in a number of studies (see sections 6.1 and 6.2), this study is unique in that it focuses on older people. The results show significant differences between older and younger users in the perception of social presence, the ability to navigate and also in the display of non verbal social behaviour.

This study also found differences in the factors related to the quality of social interaction for older and younger users. A number of factors (such as navigation and physical presence etc) were found to be significantly related to the quality of social interaction for older people. However, we still know little about why these factors are related and how they specifically affect social interaction. Such questions would need to be answered if we are to develop virtual worlds which are able to better facilitate social interaction for older people. To answer these questions, a qualitative approach is required. These questions would be examined further in the next chapter.

6.6 Limitations

One main limitation for this study was related to the study being carried out online instead of in a laboratory setting. Although this makes it possible to measure the results in a more

"realistic setting", certain external factors could not be controlled. Therefore, several steps were taken to ensure the validity of the data. First, a prior pilot study was carried out (during the development of the system in chapter 5) to ensure that participants inexperienced with 3D virtual worlds would be able to successfully use the virtual world system on their own and complete the task. The communication and position logs which were automatically recorded by the virtual world system was also reviewed to ensure that there were no technical faults and that participants had completed the task before answering the questionnaires. Two studies which had not met these criteria were excluded from analysis.

Another limitation in this study was the limited conceptualization of some of the results in this study which were measured by single item scales, particularly, the scale measuring the overall satisfaction in the user's social experience and enjoyment. Single scale items have been used to evaluate global subjective feeling of a similar nature such as overall customer satisfaction (Gupta & Steward, 1996), happiness (see (Abdel-Khalek, 2006)), job satisfaction (Wanous, Reichers, & Hudy, 1997) and enjoyment in using a machine (Ferguson & Nevell, 1996). However, using a single item scale prevents the differentiation and assessment of how each dimension of the scale is affected. This only allows us to draw a conclusion from a measure of overall satisfaction and enjoyment which was stated. Also, one of the measurements used in the analysis in this chapter (the avatar variable) had a low inter-scale reliability (around 0.63). Therefore, the results from this variable should be interpreted with caution in this study.

Chapter 7: Virtual store study to identify factors affecting social interaction for older people in 3D virtual worlds

The previous chapter reports the findings from the virtual island experiment study. Key differences were identified between older and younger users in various aspects of interaction in virtual worlds (navigation etc) and the display of non-verbal social behaviour. In addition, a number of factors were found to be related to the quality of social interaction of older and younger people.

In this chapter, the results from the virtual store experiment study are presented. The main aim of this study is to provide a more in-depth analysis on how and why the factors related to older user's characteristics and the virtual world itself have an effect on the social experience of older people in a 3D virtual environment. Doing so would address the third research question. More specifically, the objectives of this study are:

1) to analyze how certain elements of the virtual world (avatars, 3D spatial environment etc.) affect the quality of social interaction for older people and how these elements could be improved.

2) to analyze how certain aspects of older users (previous experience with computers etc.) affect their use of virtual worlds for social interaction.

3) to analyze how virtual worlds could be designed to reduce the negative effects of these aspects.

A separate virtual environment and task was used as opposed to the virtual island in chapter 6 to better address these objectives. In this study, participants were paired up and asked to carry out social interaction tasks in two virtual stores, a 3D store and a non 3D store. The main reason these two virtual stores were used instead of the virtual island was to better allow participants to examine how each element of the virtual world effect their social experience. Participants could more easily assess how each element in the 3D virtual world influence their social interaction as they could compare them in their experiences between the two stores. For instance, they could determine how useful the 3D spatial presentation of information or 3D avatars are to their social experience by comparing them with their experiences in the non 3D store, where 2D avatars were used and the store was not represented in 3D.

7.1 Study Details

A total of 40 older users participated in this study. The first pair was used to pilot the experiment and was not included in the analysis. This left a total of 38 users. The 3D and non 3D store used in this study were developed in chapter 5 (screenshots shown below in Figure

31). Similar to the virtual island study discussed in the previous chapter, participants were given a choice of 5 avatars to choose from (Old male, Old Female, Young male, Young Female and Non-human avatar). Questionnaires (similar to the one used in the virtual island study) were used to investigate how certain aspects of the virtual environment and of older people's characteristics affected their social experience. Semi-structured interviews were also carried out to augment our understanding of the results.

7.1.1 Study Procedure

Participants were recruited by snowball sampling (Heiman, 2001). Initially, older people from local church groups and volunteer organizations were contacted. Afterwards, these participants were asked to introduce other people who might be interested in participating. The criteria used in the recruitment were that participants had to be at least 55 years old. Participants with all levels of computer experience were welcomed in this study. Participants were given a shopping voucher worth £10 for their participation. Financial incentives were used in this study to compensate for the long duration of the experiment (participants had to use two virtual stores and the study lasted approximately 2 hours per session) and the potential cost of travelling to the location used to carry out the study.

Two older users participated in each session. At the beginning of each session, a brief explanation was given to explain the purpose of the study. Participants were then asked to fill in a pre-questionnaire (Similar to the one used in the virtual island experiment study, see Appendix F). Next, participants visited the registration page containing the virtual dressing room and then selected avatars to represent themselves (screenshot shown in Figure 31). Afterwards, participants proceeded to the main study. In the main study, participants were asked to enter the two virtual stores to carry out the shopping tasks, one in each store (screenshots shown in Figure 31, a screenshot of the top view of the 3D store is shown in Figure 32). Before beginning each task, participants were given a brief tutorial session lasting about 5-10 minutes. In the tutorial, the facilitator taught participants how to navigate around the store, how to purchase products and how the radar tool worked (see section 5.3.2 for a description of the radar tool). After participants were familiar enough with these concepts, they re-entered the virtual stores and started carrying out the social interaction task. Two social interaction tasks were provided for the participants in this study (one for each virtual store). In the first task, participants were asked to imagine that they were out shopping in a shop with a friend. Participants were asked to cooperate with each other to select and purchase goods necessary to organize a birthday party for their young nephew (aged 10) and five of his friends. The specific instructions given to the participants in the first task were:

"In this task, we would like you to imagine that you and your friends are going to prepare a birthday party for your friend's nephew (aged 10) and his four friends (who are about his age). You will be asked to cooperate with your partner in choosing the goods which you think are necessary to organize the party.

Both of you will be given a fixed sum of money each and any purchases will be deducted from your pool of money. You may select as many goods as you like within this fixed sum. Try to work with your partner in selecting the goods you think would be best for the party."

For the second task, participants were asked to imagine that they were going for a picnic at the local park with their friends and had to cooperate with each other to select and purchase the necessary goods for the picnic. The specific instructions given in the second task were:

"In this task, we would like you to imagine that you and your partner are planning a picnic at a local park this weekend with some of your friends (5 friends who are about the same age as yourselves). You will be asked to cooperate with your partner in choosing the goods which you think are necessary for the picnic.

Assume that you have ample time to cook and prepare the food before going on the picnic. Both of you will be given a fixed sum of money each and any purchases made will be deducted from your pool of money. You may select as many goods as you like within this fix sum. Try to work with your partner in selecting the goods you think would be best for the picnic."

As the tasks in both virtual stores where similar, prior experience of carrying out the task in the first virtual store could inadvertently influence the ability of users to carry out the task in second virtual store as participants would be more familiar with the task. To compensate for this order effect, 20 participants were asked to use the non 3D store first and then the 3D store and the remaining 18 participants used the 3D store first and then the non 3D store.

After completing each task, participants were asked to fill in a questionnaire to evaluate their experience in the virtual store they had used (See Appendix F). At the end of the session, semi-structured interviews were carried out individually with each participant. Overall, each session lasted approximately 2 hours and 30 minutes.

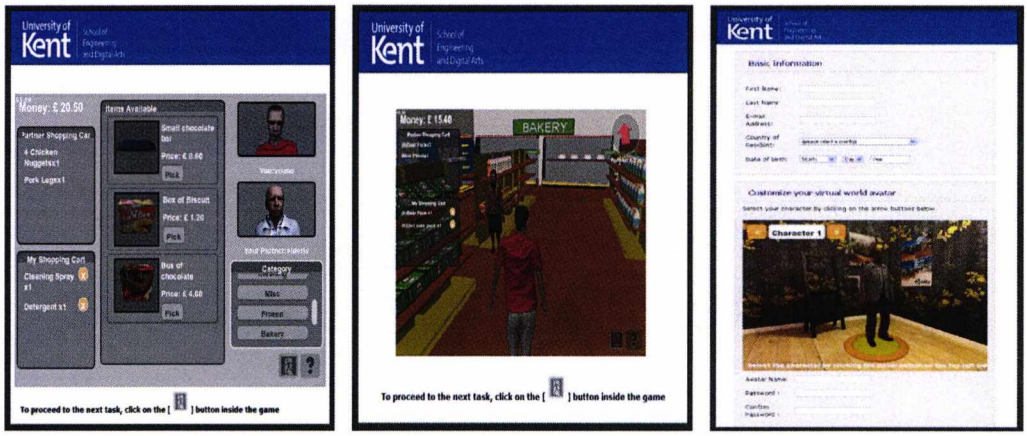


Figure 31: A screenshot of the non 3D store (left), the 3D store (middle) and the avatar registration page (right)

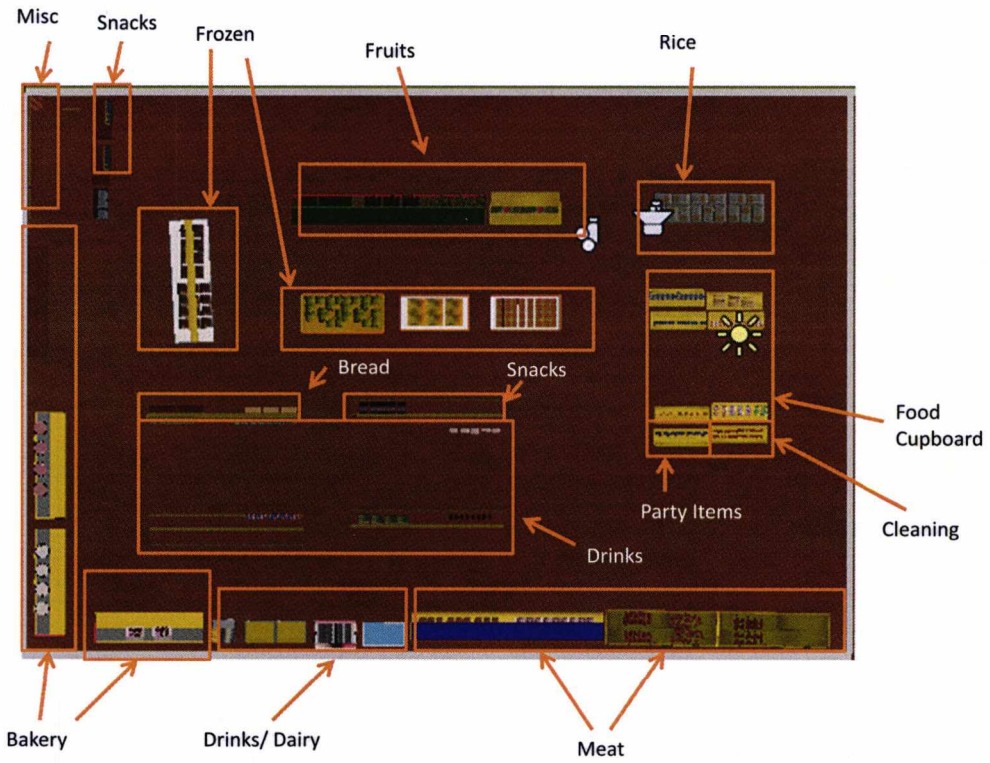


Figure 32: A screenshot of the top-view of the 3D store as shown in the Unity3D editor

7.1.2 Data collection

First, quantitative data was obtained through questionnaires. This is followed by qualitative data from semi-structured interviews. Creswell & Clark (2010) argue that data from qualitative studies could be used to enhance the findings from quantitative studies in meaningful ways, such as to provide a more detailed and complete understanding of the research topic. In this study, the qualitative data was used to provide context (help

understand the quantitative findings), illustration (provide an illustration to the quantitative findings) and explanation (help explain the relationships between the variables) (Bryman, 2012).

7.1.2.1 Questionnaire

The questionnaires used in this study are similar to the ones used in the virtual island study in chapter 6. A pre-study questionnaire was used to gather data about the demographics and characteristics of the participants and a post questionnaire was used to examine their experience with the virtual world. Key measures used to evaluate the quality of social interaction experience include *social presence, perceive quality of communication, perceived task performance and overall satisfaction with social experience*. In addition, questions were also used to measure user characteristics which include *computer experience, scepticism in using CMC technology to communicate, computer anxiety and health* and platform factors which include *physical presence, the avatar and navigational ability*. Finally, *enjoyment* and *previous level of acquaintance* were also examined. Please see section 6.3.2.1 for more information related to the questions and measures used in the questionnaire. Note, in this study, experience with voice communication software was measured instead of experience with text messaging programs in the computer experience section as the virtual world in this study used voice communication.

7.1.2.2 Semi-structured interviews

Semi-structured interviews were also carried out to investigate the social interaction experience of participants in the virtual world. An "interview guide" consisting of questions covering factors which had potential to affect the social interaction experience of older people as identified from the literature review were prepared as part of the semi-structured interview process (Bryman, 2008). These questions were aimed at deepening our understanding of how each of the factors affected social interaction for older people.

First, open-ended questions were asked to encourage participants to discuss their experience of using the virtual stores in the following categories:

a. *Overall experience:* Participants were first asked a generic question to discuss their overall experience in the virtual stores ("Could you please tell me how your experience was in the two virtual stores?")

b. *Experience in collaborating/communicating in the 3D store*: Participants were asked to discuss their experience of communicating and collaborating with another user in a virtual environment and the particular factors which they felt facilitated or impeded their interaction and communication. ("How did you feel about communicating and collaborating with the other person in the virtual store, in this aspect, which virtual store do you think was better? Why?")

c. *Preferences*: Participants were asked to discuss what they enjoyed/disliked about the two virtual stores ("Was there anything you liked/disliked in either of the virtual stores? Why did/didn't you like them?").

Next, probing questions related to the specific aspects of the platform and the user characteristics which were identified from the review of literature (see section 6.1) were asked. The following domains were covered.

a. *The Avatar*: Participants were asked to discuss the reasons for choosing their avatar and how this affected their social experience. They were also asked whether they preferred the 3D characters or the 2D characters and the reasons why.

b. *3D spatial element*: Participants were asked to compare their experience of shopping online in the 3D and non 3D store. In particular, they were asked whether the spatial 3D environment ("The ability to move around the store in 3D and communicate") had any implications to their social experience.

c. *Navigation:* Participants were asked to discuss the ease/difficulty of navigating in the virtual stores and whether this had any effect in regards to their social experience. If they felt navigation was difficult, participants were also asked to discuss the reasons why they felt it was difficult.

d. *Presence:* Participants were asked to discuss the realism of their shopping experience (*Physical presence)* and how much they perceived the presence of their partner as they used the virtual stores to carry out the task (*Social presence*).

e. *General perception towards using virtual worlds:* participants were asked to discuss the implications of using such technologies for social interaction and whether they had any concerns of using virtual worlds in this context.

7.1.3 Data analysis

SPSS 18[28] was used to analyze the data from the questionnaires. To compare the differences in the quality of social interaction between the two platforms, T-tests were conducted. T-tests were also carried out to compare the differences in the perception of physical presence, the value of the avatar and ease of navigation between the two platforms. Correlation and Regression analysis were carried out to test how older people's characteristics and how factors related to the virtual world affected the quality of social interaction.

To analyze the interview data, first, the audio recordings from the interviews of 36 participants were transcribed (the data from one pair of participants was not available due to technical difficulties in recording). Altogether, there was approximately 19 hours worth of data. The qualitative data analysis software Atlas.ti[29] was used to help in the coding and analysis of the data. The data was analyzed using thematic analysis (Braun & Clarke, 2006). I adopted a similar approach of thematic analysis as described in the study in Chapter 3. This

[28] http://www-01.ibm.com/software/analytics/spss/
[29] http://www.atlasti.com/index.html

includes first re-reading the transcripts to gain an overview of the key topics and then coding the data. The codes were then separated broadly into 3 main categories; whether they referred to their general characteristics of the participants, their interaction with the 3D virtual store or their interaction with the non 3D virtual store. Afterwards, codes of a similar nature were then grouped together into themes. The themes were then reviewed against the overall data and then refined.

7.2 Questionnaire Results

Reliability tests were carried out to examine the statistical reliability of the multi-item measures used in this study. The results showed good statistical reliability on all variables except for the scepticism of using CMC technology. Therefore, this measure was removed from the analysis in this study. Table 17 shows the Cronbach's alpha value for each measure.

Measure	Cronbach's alpha
Social presence	0.87
Quality of Communication	0.88
Efficiency of task performance	0.81
Scepticism	**0.40**
Anxiety	0.87
Health	0.86
Physical presence	0.90
Navigation	0.87
Avatar	0.90

Table 17: The statistical reliability of the measures used in the questionnaire in the virtual store study

7.2.1 Participant demographics and characteristics

Overall, data from 38 older participants were analyzed. The key characteristics of these participants are shown in
Table 18.

Variable		Value
Gender	Male	16
	Female	22
Age		Mean=66.84 (SD=6.55) (Min 55, Max=82)
Prior Experience (Out of 10)	Computer	Mean=8.57 (SD=2.4)
	Internet	Mean=8.08 (SD=2.27)
	E-mail	Mean=8.24 (SD=2.20)
	Skype	Mean=3.43 (SD=1.59)
	3D Games	Mean=2.54 (SD=1.37)
Level of acquaintance (Out of 5)		Mean=3.79 (SD=1.6)
Anxiety (Out of 5)		Mean=1.96 (SD=1.00)
Health (Out of 5)		Mean= 2.00 (SD=0.96)

Table 18: A summary of the demographics and characteristics of the participants in the virtual store

The results showed that most of the participants were familiar with computers, the internet and E-mail, but had little experience with voice communication programs or 3D games. Participants in the study also had quite low levels of computer anxiety. Overall, participants had only minor difficulties in regards to their health. Also, as participants were recruited by snowball sampling, participants were already quite well acquainted with their partners.

7.2.2 Avatars

Table 19 shows the type of avatars selected by the participants in the virtual store study.

Avatar	Gender	
	Male	Female
Old Male	70.6%	4.8%
Old Female	0.0%	23.8%
Young Male	11.8%	9.5%
Young Female	5.9%	42.9%
Non-Human	11.8%	19.1%

Table 19: The type of avatars selected by the participants in the virtual store study

As shown in Table 19, the male participants overwhelmingly preferred older male avatars. For female participants however, the young female avatar was the most popular, followed by the older female avatar.

During the interviews, participants were asked to describe the reason they chose their avatar. The most popular reason given by male participants was that they decided to select avatars which best resembled their physical world appearances (9 participants). The female participants who selected the old female avatar also reported a similar reason (5 participants). One reason participants selected such avatars was they did not want to use avatars which misrepresent their real age and gender.

"Well I didn't want to be a robot [Referring to the non human character], I didn't want to be male and much as I'd love to be young and slim, I [am not] so I just felt that... you know, I suppose that I'm probably affected by the stories you read of people online pretending to be something they absolutely are not." (Participant 21, Female, 66, selected the older female avatar)

I chose that one because it simply looked like me, the other one was a younger man, very much younger in appearance and that's not the way I feel or want to be represented. It wouldn't have bothered me if I had chosen it, but my choice was to be nearest to my image. I like an avatar that would be more similar to me. (Participant 22, Male, 65, selected the old male avatar)

A number of older people also selected avatars which were younger than their actual age or were of a different gender. What was particularly interesting was that the majority of the female participants selected the young female avatar. The reasons given for this was because

they wanted the avatars to reflect their personality and outlook of them still being young (3 participants). This is similar to the finding from other studies. Duecheneaut et al (2009) found that female users tended to prefer avatars which were of similar appearance to their idealized selves and users seemed to customize their avatars to make them look younger than themselves. This seems to be the case for some of the older participants in this study as well.

"[I chose this avatar] because I feel I think of myself as young. I've got a young outlook to life."
(Participant 4, Female, 61, selected the young female avatar)

"Umm... she was nice and slim... she was female... I felt... umm... I wouldn't mind looking like her... she was young... I think it took me back to my youth....."
(Participant 14, Female, 69, selected the young female avatar)

Other reasons given were that participants felt these young avatars were the most realistic or best suited to the context of the task (shopping) (2 participants).

"Why did I chose the young ones??? umm... because an alien wouldn't go shopping in that sort of shop, full stop..the older two people are too academic looking, so they wouldn't be shopping like that... they weren't dressed correctly to go shopping...the two young people, they dress more suitably for this task" (Participant 32, Female, 66, selected the young female avatar).

Another reason users selected a younger avatar or one with a different gender was that participants did not select the avatar to represent themselves, but to represent a family member or a shopping companion (3 participants).

"I chose for someone who looked like my daughter and so I choose my daughter's name"
(Participant 29, Female, 67, selected the young female avatar)

"I choose the avatar because generally if you're a couple and you are shopping, you generally are with a man or a husband or a partner
(Participant 20, Female, 74, selected the old male avatar)"

As for the non human avatars, participants reported selecting them for their entertainment value. Three participants reported selecting the non-Human avatar either "for fun" or due to the perception of their experience in the virtual world as being unreal or similar to a video game and selected an avatar to match that context. The perception of their experience in virtual worlds as being similar to computer games is further discussed in section 7.3.2.

"I suppose because, partly for a bit of fun, but also because it's not a real situation and therefore, I felt that I didn't really want to pretend to be a person"
(Participant 10, Male, 62, selected the non-human avatar)

"I don't know, to me an avatar is an alien. I mean I don't think I've seen avatars.... I think it was the fact that I felt I was playing a game more than it was real life. So that's why it seemed right

to chose something that looked like an alien or avatar in this context"
(Participant 34, 67, Female selected the non-human avatar)

The avatar selection results from this study were similar to the results from the study in the previous chapter. The majority of the male participants selected the old male avatar and the majority of the female participants selected the young female avatar. However, in this study, some of the older participants selected avatars which had different genders from themselves. As explained previously, some selected such avatars to represent their shopping partners or their family members.

7.2.3 Differences between the 3D and non 3D store

T-tests were carried out to analyze the differences in the quality of social interaction and the various aspects of interaction (physical presence etc) between the two platforms. Table 20 shows the results.

Variable		Non 3D	3D	Significance
Quality of social interaction	Social presence (Out of 5)	Mean=3.53 (SD=1.00)	Mean=3.44 (SD=1.01)	Not significant (t(74)=0.40,p=0.70)
	Quality of communication (Out of 5)	Mean=4.27 (SD=0.608)	Mean=4.12 (SD=0.826)	Not significant (t(74)=0.87,p=0.39)
	Performance (Out of 5)	Mean=4.44 (SD=0.57)	Mean=4.23 (SD=0.90)	Not significant (t(74)=1.26 ,p=0.21)
	Overall satisfaction with social experience (Out of 5)	Mean=3.55 (SD=1.27)	Mean=3.37 (SD=1.403)	Not significant (t(74)= 0.60, p=0.55)
Enjoyment (Out of 5)		Mean=4.05 (SD=1.06)	Mean=3.95 (SD=1.25)	Not significant (t(74)=0.40 , p=0.69)
Platform factors	Physical presence (Out of 5)	Mean=2.51 (SD=1.24)	Mean=3.08 (SD=1.22)	Not significant (t(74)=-1.98, p=0.052)
	Navigation (Out of 5)	Mean=4.09 (SD=0.86)	Mean=3.04 (SD=1.14)	**Significant** t(74)=4.54,p<0.001
	Avatar (Out of 5)	Mean=2.00 (SD=1.19)	Mean=3.07 (SD=1.18)	**Significant** t(74)=-4.10,p<0.001

Table 20: Differences in the quality of social interaction, enjoyment, perception of physical presence, navigation and the value of the avatar between the non 3D and the 3D store.

As seen in Table 20, there was no significant difference in the measures for the quality of social interaction between the 3D and non 3D store. There was also not a significant difference in the overall satisfaction in the social experience and enjoyment between the two virtual stores.

Participants found it significantly easier to navigate in the 2D store than the 3D store. Participants also felt that the avatars in the 3D store played a more prominent role than the avatars in the non 3D store (See Figure 33 for details of the non 3D and 3D avatars). However, there was not a significant difference in physical presence.

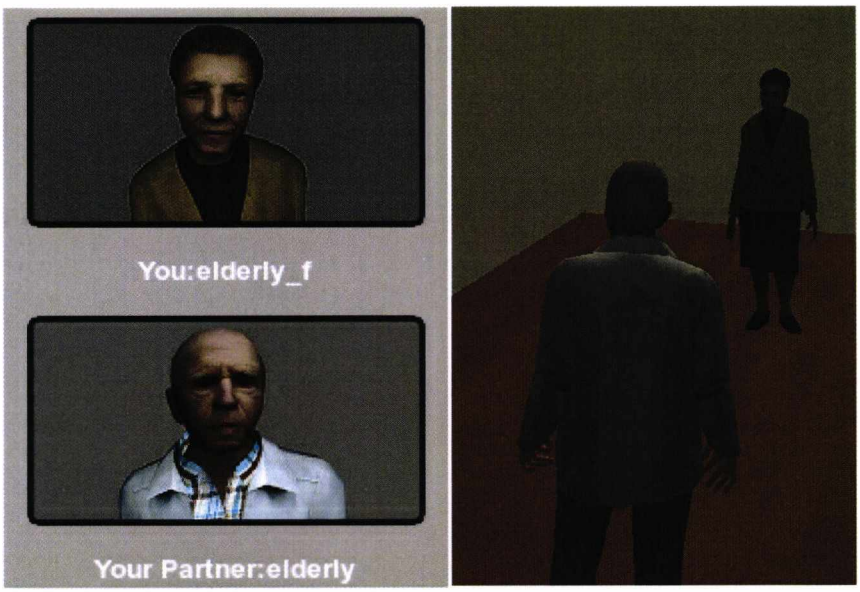


Figure 33: A comparison between the non 3D avatars (left) and the 3D avatars (right).

Next, gender differences were analyzed. T-tests showed that there was no significant difference between social presence, quality of communication, performance, enjoyment, ability to navigate, the value of the avatar and physical presence in the 3D and non 3D store. In regards to overall satisfaction in the social experience however, older females (Mean=3.56) reported significantly higher levels of satisfaction than older males (Mean=2.81) ($t(74)=-2.187$, $p<0.05$) for the 3D store. No significant difference was found for this measure in the non 3D store.

7.2.4 Factors which influence the quality of social interaction in the 3D and non 3D virtual store

First, the relationship between the user characteristics (user factors), the platform factors and the measures for the quality of social interaction were examined. Pearson's correlation tests were carried out to examine these relationships. Significant results are shown in Table 21.

		PRE	NAV	AVA	GAME
SP	Non 3D	**0.51****	0.29 (p=0.08)	0.26 (p=0.11)	0.13 (p=0.43)
	3D	**0.68****	**0.54****	**0.47****	**0.34***
QOC	Non 3D	**0.34***	**0.44****	0.21 (p=0.20)	0.28 (p=0.09)
	3D	**0.39***	**0.35***	0.20 (p=0.22)	0.12 (p=0.49)
PER	Non 3D	0.27 (p=0.10)	**0.38***	0.17 (p=0.30)	0.16 (p=0.35)
	3D	**0.45****	**0.49****	0.27 (p=0.10)	0.24 (p=0.15)
SAT	Non 3D	**0.56****	**0.48****	**0.41***	0.18 (p=0.29)
	3D	**0.78****	**0.67****	**0.65****	0.29 (p=0.08)

** indicates that correlation is significant at the 0.01 level (2 tail), * indicates that correlation is significant at the 0.05 level (2 tail)

Note: Level of acquaintance, Anxiety, Computer, Internet, Skype and e-mail variables were not shown as they had no significant correlations towards the measures for the quality of social interaction.

Note: Abbreviations: (SP=social presence, QOC= quality of communication, PER=Performance, SAT=overall satisfaction with social experience, PRE=physical presence, NAV=navigation, AVA=avatar, GAME=game experience)

Table 21: A table summarizing the factors which correlate (Pearson's correlation 2-tailed) with the quality of social interaction measures for the non 3D store and the 3D store. Only variables with significant results are shown.

Next, I examined the factors linked to enjoyment. Pearson's Correlation tests showed that physical presence ($r(38)=0.624$, $p<0.001$), navigation ($r(38)=0.607$,$p<0.001$) and the avatar ($r(38)=0.623$,$p<0.001$) were correlated with enjoyment for the 3D store. For the non 3D store, these factors were also correlated but to a lesser degree (Physical presence ($r(38)=0.469$,$p<0.01$), navigation ($r(38)=0.34$, $p<0.05$) and the avatar ($r(38)=0.387$, $p<0.05$)).

Multiple regression analysis was then carried out to test the degree which the user and platform factors influenced each quality of social interaction measure. Person's correlation tests showed that the variables experience with computers, the internet and e-mail had an almost perfect correlation (all higher than 0.95). Field (2009) suggested that independent variables with correlations higher than 0.8 be removed to prevent Multi-collinearity. Therefore, experience with computers and internet were removed (as users who were experienced with e-mail would most likely already have experience with computers and the internet.)

As the model building was exploratory, variables were entered using the stepwise method (Field, 2009). The user factors which were entered were experience with E-mail, Skype, 3D

games, computer anxiety, level of acquaintance and health. These were further divided into two groups (computer experience and general characteristics). This was done to examine the effect of computer experience (E-mail, Skype, 3D games) separately from the other user characteristics (computer anxiety, level of acquaintance and health). The platform factors entered were perceived physical presence, navigation and avatar. Multiple regression analysis was used to test the variables in each of these groups against each measure of the quality of social interaction (social presence, quality of communication, performance and overall satisfaction in social experience) and enjoyment. Therefore, a total of 15 models were tested (3 groups were tested for each of the 5 variables) for each condition (3D and non 3D).

Multi-collineratiy within the regression models were assessed by examining the VIF (Variance inflation factor). All variables in the model had a VIF of less than ten and the average VIF was not substantially greater than 1, indicating that Multi-collinieraity within the variables was minimal (Bowerman & O'Connell, 1990). The results of the analysis are as follows for the 3D store:

- **Social presence:** When all the computer experience variables were entered, only experience with 3D games had a significant impact on the level of social presence (standardized beta =0.34, $p<0.05$). However, this predictor accounted for only a small percent of the variance (Adjusted $R^2=.090$, $F(1,36)=4.54$, $p<0.05$)). None of the general characteristic variables were significant predictors of social presence. When examining the platform variables, only physical presence significantly impacted social presence (standardized beta=0.68,$p<0.001$). This model accounted for 44.9% of the variance (Adjusted $R^2=0.45$, $F(1,36)=31.10$, $p<0.001$)

- **Quality of communication:** No significant predictors of the general characteristics or computer experience variables influenced the quality of communication. Only physical presence significantly impacted the quality of communication (standardized beta =0.39, $p<0.05$). However, the model only accounted for 12.6% of the variance (Adjusted $R^2=0.126$, $F(1,36)=6.36$, $p<0.05$).

- **Performance:** No significant predictors of the general characteristics or computer experience variables influenced perceived performance. As for the platform factors, only navigation significantly impacted perceived performance (standardized beta =0.49, $p<0.01$). The model accounted for 22.0% of the variance (Adjusted $R^2=0.22$, $F(1,36)=11.43$, $p<0.05$).

- **Overall satisfaction in social experience:** No significant predictors of the general characteristics or computer experience variables influenced overall satisfaction with social experience. When looking at the platform factors, physical presence (standardized beta =0.59, $p<0.001$) and navigation (standardized beta=0.28, $p<0.05$) were significant predictors of overall satisfaction in social experience. The model accounted for 62.5% of the variance (Adjusted $R^2=0.63$, $F(2,35)=31.843$, $p<0.001$).

- **Enjoyment:** No significant predictors of the general characteristics or computer experience variables influenced enjoyment. As for the platform factors, both physical presence (standardized beta =0.39, $p<0.05$) and navigation (standardized beta =0.34, $p<0.05$) significantly impacted enjoyment. The model accounted for 42.3% of the variance (Adjusted $R^2=0.423$, $F(2,35)=13.148$, $p<0.001$).

Next, the same factors were examined for the non 3D store:

- **Social presence:** No significant predictors of the general characteristics or computer experience variables influenced social presence. Examining the platform variables showed that only physical presence significantly influenced social presence (standardized beta=0.51, $p<0.001$). This model accounted for 24.2% of the variance (Adjusted $R^2=0.24$, $F(1,36)=12.83$, $p<0.001$)

- **Quality of communication:** No significant predictors of the general characteristics or computer experience variables influenced the quality of communication. For the platform factors, only navigation significantly influenced the quality of communication (standardized beta =0.44,$p<0.01$). However, the model only accounted for 16.8% of the variance (Adjusted $R^2=0.169$, $F(1,36)=8.49$, $p<0.01$).

- **Performance:** No significant predictors of the general characteristics or computer experience variables influenced perceived performance. As for the platform factors, only navigation significantly impacted the perceived performance (standardized beta =0.38, $p<0.05$). The model accounted for 12.0% of the variance (Adjusted $R^2=0.12$, $F(1,36)=6.06$, $p<0.05$).

- **Overall satisfaction in social experience:** No significant predictors of the general characteristics or computer experience variables influenced overall satisfaction in social experience. When looking at the platform factors, navigation (standardized beta =0.41, $p<0.01$) and physical presence (standardized beta =0.50,$p<0.001$) were significant predictors. The model accounted for 44.9% of the variance (Adjusted $R^2=0.45$, $F(2,35)=16.07$, $p<0.001$).

- **Enjoyment:** No significant predictors of the general characteristics or computer experience variables influenced enjoyment. As for the platform factors, only physical presence (standardized beta =0.47, $p<0.01$) significantly influenced enjoyment. The model accounted for 19.8% of the variance (Adjusted $R^2=0.198$, $F(1,36)=10.14$, $p<0.01$).

A summary of the results of the multiple regression analysis is shown in Table 22.

		Adj R^2	Platform factors		User factors (computer experience)
			PRE	NAV	3D Games
SP	Non 3D	0.24**	.52**	-	-
	3D	0.45**	.68**	-	-
		0.09*	-	-	0.34*
QOC	Non 3D	0.17**	-	.44**	-
	3D	0.13*	.39*	-	-
PER	Non 3D	0.12*	-	.38*	-
	3D	0.22*	-	.49**	-
SAT	Non 3D	0.45**	.50**	.41**	-
	3D	0.63**	.59**	.28*	-
ENJ	Non 3D	0.20**	.47**	-	-
	3D	0.42**	.39*	.34*	-

** indicates significance at the 0.01 level (2 tail), * indicates significance at the 0.05 level (2 tail)

Note: Level of acquaintance, Anxiety, and Health (variables in the *General characteristics* group), e-mail, skype (variables in the *Computer experience* group) and avatar (variable in the *Platform factors* group) were not shown as they were not significant predictors to the measures for the quality of social interaction.
See appendix G for the non significant predictors excluded by the step-wise method

Note: Abbreviations: SP=social presence, QOC= quality of communication, PER=Performance, SAT=overall satisfaction with social experience, ENJ= overall enjoyment, PRE=physical presence, NAV=navigation

Table 22: A table summarizing the regression results in the virtual store study

Overall, the results show that physical presence was a key factor to many of the measures for the quality of social interaction in the 3D store, including social presence, quality of communication, overall satisfaction in social experience and enjoyment. For the 3D store, navigation was also important. Analysis showed that this factor was a significant predictor of performance. Part of this could be expected as a major component of the task that was given required participants to move around in the 3D store to find appropriate products. This factor was also found to be a significant predictor of overall satisfaction in social experience and enjoyment when other platform factors were controlled. The avatar however, was not found to be a significant predictor to any of the measures.

Despite navigation and the avatar correlating with variables such as social presence and quality of communication, the results from the regression analysis showed that they were not significant predictors of such variables. Part of this could be because these two factors indirectly influence these measures through physical presence and the remaining variance

not explained by physical presence was not a significant predictor of these measures. For instance, in social presence, when not controlling for physical presence, single variable regression analysis also showed that Navigation (standardized beta= 0.535, $p<0.01$), (Adjusted $R^2=0.27$, $F(1,36)=14.45$, $p<0.001$) and the avatar (standardized beta=0.47,$p<0.01$), (Adjusted $R^2=0.20$, $F(1,36)=10.02$, $p<0.01$) each significantly predicted social presence. In addition, a multiple regression test with physical presence as a dependant variable and navigation and avatar as predictor variables showed that both factors were significant predictors of physical presence (standardized beta =0.50, $p<0.01$ for the avatar and standardized beta= 0.33, $p<0.05$ for navigation) (Adjusted $R^2=0.56$, $F(2,35)=24.137$, $p<0.001$) in the 3D store. In the non 3D store, single variable regression analysis showed that both navigation and avatar were not significant predictors of social presence.

As for the user factors which were investigated, only experience with computer games was found to be significantly correlated with the measures used to evaluate social interaction experience for older users. Regression analysis also showed this factor to be a significant predictor of social presence.

7.3 Analysis of interview data

Thematic analysis was used to analyze the interview data. The themes identified from the analysis were categorized together based on their content. 4 key topic areas emerged. The first covers factors related to the social interaction experience of users in the 3D virtual world. The second is related to the difficulty of older participants in suspending disbelief and immersing themselves in the virtual environment. The third is about the user barriers which effect interaction in 3D virtual worlds and the final is related to future implications of the technology.

7.3.1 Social interaction experience in the 3D virtual world

The questionnaires showed that there was no significant difference between the measures for the quality of social interaction between the 3D and non 3D store. This observation was further articulated in the interviews. 14 of the participants reported no difference in their communication and collaboration experience between the non 3D and the 3D store. The main reason seems to be that participants felt that the audio and not the visual aspects (such as the visual avatars) were of more importance to their communication experience (this was reported by 15 participants).

"I think the communication was the same, the only difference was the 3D is that you've got movement and a bit more activity. But I think the important part for me is the communication, not the visual" (Participant 10, Male, 62).

"If you were talking to the headphone, you would be taking as well, so you could get more from

the voice...I think I would try to have more from the voice than from the avatar" (Participant 30, Female, 61).

The 3D spatial presentation of the store was helpful in other aspects however. For instance, some of the participants reported enjoying the experience of being able to move around in a 3D store (11 participants).

"Participant 22: The 3D store, without a doubt... the 3D store was much more fun.

Interviewer: What about the 3D store did you find enjoyable?

Participant 22: Yes, being able to walk around, navigating, going up to the counter and having the food identified by a little logo, very interesting, very useful" (Participant 22, Male, 65).

In regards to social interaction a number of participants felt that certain limitations of the 3D spatial environment and the avatars restricted their social experience. Two major factors were identified from the interviews. First, participants seemed to have a difficulty in associating the avatars with physical people. Second, participants reported the lack of non-verbal cues in communication as a key factor restricting their social experience.

7.3.1.1 Difficulty in associating a visual avatar with physical people

One commonly reported theme in the interviews was the difficulty of older users in associating the avatars in the virtual world with real people. 16 participants reported some kind of difficulty in associating themselves or their partners with the avatars when communicating in the 3D virtual world.

"Well, to put it this way, he[the avatar] was a nice looking chap, but it wasn't him, you know, I couldn't think of him as being [Participant 2], he wasn't a man I was going shopping with, so it didn't make it real in a way,[It seems I was] shopping with a stranger" (Participant 1, Female, 64).

"you are not really meeting a real person, you are meeting an avatar, you are meeting something that is put in place of a real person" (Participant 2, Male, 62).

Part of this was due to a perceived discrepancy between the visual avatars and the audio communication in the virtual world. For these participants, the social presence of their partners mainly came from their partner's voice which they felt was separate from the visual representation of the avatar. Therefore, this made it harder from them to associate the avatars with the person they were communicating with. This was reported by nine of the participants.

"I'm quite happy talking to people through a computer... just the voice.... it's funny... it's linking the voice to an avatar that's the no-no for me." (Participant 29, Female, 67)

"She was hiding behind her avatar, I was hiding behind my avatar..those two avatars does not represent us as we are now... so it was a dual function if you like... we were communicating by phone[audio], our avatars were running around the store buying [products]" (Participant 25, Female, 67).

Another reason why participants felt it was difficult to associate the avatars with their partners seems to be due to the visual appearance of the avatar not matching the true appearance of their partner. This was mentioned by seven of the participants.

"It was odd to see [Participant 12] in a different guise. It's a sort of disguise shall we say. But it was good, slightly weird because she didn't look like [Participant 12], quite. And you think "Who's this lady I'm talking to" That does come to the back of your mind" (Participant 11, Male, 70).

"I don't know, I don't know why it didn't [feel like my partner].Although he chose a sensible one [Avatar] didn't he? When he turned around it wasn't him. It wasn't his face wasn't it? I didn't feel it was him." (Participant 34, Female, 67).

A considerable number of older users also reported preferring to have avatars with appearances that match the actual characteristics of the people they represent. This could be seen during the selection of the avatars (see section 7.2.2) where 14 participants reported selecting avatars which were most similar in appearance and characteristics to themselves. In addition, during the interviews, eight participants also reported wanting avatars to be more similar in visual appearance to their partners and six reported wanting to be represented by avatars with more similar appearances to themselves.

"Well if it is going to be an avatar I want it to look like me and I want it to look like my partner not a strange person" (Participant 14, Female, 69).

Further support for the importance of the appearance of the avatar to the older users could be found in their discussion about the non-human avatar. Nine participants reported some form of negativity towards the non-human avatar or that these avatars negatively affected their communication experience (such as lowering the perceive realism of their experience).

"Participant 34:...I think If he had an alien chap as well, I think it would have felt really weird trying to do shopping with an alien

Interviewer: Why did it feel weird?

Participant 34: I don't know, you don't shop with aliens, don't you.....you don't really see that in the real world. If you wanted to be serious about it, you would have to have serious people that look a bit like people, rather than something from out of space." (Participant 34, Female, 67)

A previous study related to older people's perception of avatars also reported a similar result. Cheong et al (2011) found that older people reported a low level of Homophily with the avatars which suggested that they could have difficulty relating and identifying themselves to the avatars. Similarly, in this study, older people seemed to find it difficult to not only embody themselves with the avatars, but also found it difficult to perceive the avatars as representatives of their partners as well.

7.3.1.2 Lack of non-verbal communication

One frequently mentioned limitation in regards to avatar mediated communication was the lack of non-verbal communication. Participants felt that the inability of avatars to display facial expressions and other forms of body language had a significant impact to their social experience in this platform. Participants also mentioned that they wanted to be able to use gestures to aid in communication (such as control their avatars to point to products in the store). Overall, this theme was reported by 17 of the participants interviewed.

"In a sense that the avatars were... more or less grotesquely inhuman. I mean my character the man, one could see that he was especially designed to be a man, but you wouldn't necessary be able to pick up body language in the way which he appear, and you certainly wouldn't picked that from the one that my wife choose, who was more of the monster figure [non human avatar]... Amusing and you've got that geographical sense of being closer or further apart, but that means of communication which is dependent on body language was missing" (Participant 2, Male, 62).

"I think what you lose with virtual reality which you don't have...what you lose is the sort of visual expression, if I'm talking to you, I can smile at you or I can change the tone of my voice, If you've got communication you can pick it out from that. People say you sometimes you can detect a smile by the tone of people's voice. I think eye contact and people's expressions are an important part of communication. I don't think you can recreate that. I think a program can be developed to a point where you can have that as well. Those are important aspect of communication I think....The non visual cues" (Participant 10, Male, 62).

The importance of non verbal cues in avatar mediated communication has been frequently reported in past studies (see (Bente & Kramer, 2011)). During the interviews, older people in this study stressed how important such cues were for them in communication. For some, the inability to perceive these non-verbal cues also impacted the perceived realism of their experience.

"When you communicate, you need your eyes, you need your hands, when your get to know somebody as a prospective partner, it's to do with a smile and everything. All this is lacking in the 3D and that isn't real enough for me" (Participant 7, Female, 61)

In addition, one participant reported that the inability of avatars to display facial gestures made her feel they were emotionless and made her perceive the avatars as less humane. Two participants even reported that their inability to display emotions and their awkward movements made them feel more like robots. This could be another reason older people had difficulty associating avatars with actual people. Other participants felt that the lack of such cues limited the efficiency of their communication and made it more difficult to trust their partners as they felt that users could hide their emotions and body language during communication.

7.3.2 Difficulty in suspending disbelief

Most of the participants reported a sense of artificiality when engaging with the 3D store and felt that their experience was not real enough. It would seem that it would take a high level of detail to be able to allow some of the older people to suspend their disbelief and immerse themselves in the virtual world. Some of these might be difficult to replicate with the capacity of current personal computers.

A variety of factors have been frequently cited to reduce the participant's sense of realism in the 3D virtual store. Older people had a tendency to compare their experiences in the virtual world with experiences in the physical world and report any discrepancies as making their experience feel unreal and not satisfying. For instance, seven participants reported the inability of computers to transmit senses available in the physical world (such as touch, smell etc) as a key disadvantage.

"In the virtual, you can't do that, you can't feel the paper cups. If I'm buying the paper plates I would like to feel whether the paper plates has the ability to hold things, what I'm planning to keep or if it would just bend and not be strong enough... I particularly remember about the paper plates, because in some places you go to a party and they give you plates which are so light that you can't even hold it in your hand... That information I don't know how you are able to include it in a virtual store. The feeling, it is a different thing. In a virtual thing you can't feel that" (Participant 3, Female, 73)

"I really can't visualize myself shopping on a computer, so perhaps I'm a person you need to convert because of what you can see, you are very limited as to what you can see, can smell and... on a computer screen" (Participant 13, Female, 67)

Participants also felt that compared to a shop in the physical world which is usually crowed with customers and staffed, the lack of other actors in the virtual store made their experience seem less realistic (9 participants).

"I didn't feel like I was in the store at all... I didn't get the feeling of going shopping.... Umm..... Because there aren't any real people there.... you know, in the supermarket, with me, I tend to talk to people...but here it is only one-to-one...." (Participant 26, Female, 62)

Other limitations such as the lack of details and information about a product (8 participants) and the lack of variety of products available in the virtual store (17 participants) were also reported. What was particularly interesting was that in other online shopping environments (non 3D), older people also had a tendency to report similar discrepancies between the virtual store and the physical one (wanting to speak to a store clerk etc) (Sjölinder, Höök, & Nilsson, 2000).

Because of this perceived artificiality, participants often reported that they felt their experience in the 3D store was more similar to a video game experience (14 participants). For participants, the perception of "controlling a character" to move around a computer generated virtual store was similar to the kind of games they had played earlier in their life or had seen their younger family members play.

"To me I felt that the whole experience in the virtual store was more like a game than serious shopping. I think because it's like cartoon... it's almost like doing a game... a computer game rather than going shopping....All of it... (the avatars, the products), the whole thing is like cartoon" (Participant 26, Female, 62).

"It was a game really... You are pressing these knobs making a little figure do things... It's just like a game that my grandchildren play. Making figures do things...hitting each other and shooting each other or jump off something. It's the same really."
(Participant 32, Female, 66)

Participants also often used words such as "play" and "have fun" to describe their experience in the 3D virtual store (17 participants). Compared to the non 3D store which participants perceived as being more practical and task oriented, participants felt that the 3D store had a more playful element within it.

"The 3D one is more playing around... <Laugh>... it's quite fun but I don't know you see. I'm not house bound...I can go to the shop, walk about if I want to... but it's a different experience. It's a different thing. The 3D one is playing around and the 2D one is doing a job" (Participant 32, Female, 66)

For instance, one participant described how her experience in the 3D virtual world was similar to playing with a dolls house.

"Well, it was a world on a screen anyway, it was a world in miniature. When you are playing as a girl... playing a dolls house, you can put your people where you wanted... that sort of thing...so it's similar to a dollhouse...that's how I feel.... that was the fun aspect, if you've got to go shopping for cat food, bread and milk, that's nice to do it that way" (Participant 30, Female 61)

Older people often associated such activities with the younger generation (Five of the participants specifically mentioned games played by their child or grandchildren during the interviews and compared it to their experience with the 3D virtual store). This could explain why some of them felt that these virtual worlds were more suited to the younger generation,

who they felt would be more comfortable in engaging with "computer games" and therefore 3D virtual worlds (9 participants).

"I would have thought in certain setup there could be advantages; I mean probably more for younger people who are much more into computer games. They're probably so much used to this, and I could well see that for them it could be great. I suppose that I'm just not really used to it. It feels really unreal for me." (Participant 1, Female, 64)

For some, this perception of the 3D virtual world as being "playful" and a "game" was one of the reasons which made them perceive their experience as being less real. The perception of games as unreal or fabricated constructs made participants less willing to immerse themselves in the virtual world.

"Interviewer: So is there anything about the stores that made your experience feel more real or less real?

Participant 27: I didn't think along these lines at all... as far as my mind was thinking... it's a game. I didn't get into the character of the things." (Participant 27, Male, 64)

7.3.3 User barriers

A number of barriers to the acceptance of this technology which were related to older users themselves could also be discerned from the interviews. One theme was related to older people's negative perception towards online technologies, in particular towards CMC. From the interviews, eight participants expressed concerns about the safety of such technologies, especially related to the use of false identity, privacy and the dangers of being deceived.

"I must admit... but it just... the concept just um...because you don't know the person in the other end, that had become a little bit.... if I use the word sinister... it's not quite the word... when there has been bad news like when a child has just been abducted...all this... that sort of thing.. quite often it's in these so called chat rooms." (Participant 26, Female, 62)

In addition, participants expressed a general discomfort towards developing relationships online through a computer as opposed to meeting face-to-face. This was reported by six of those interviewed.

"I can't actually see myself doing that on a computer. I'm too weary. I would do it in real life. I have no problem talking to somebody in real life anywhere in any situation, but on a computer I would think a 121 times and still come up with no" (Participant 13, Female, 67)

Similar concerns were also often cited when participants were asked about the implications of using virtual worlds for social interaction with other users. Some participants expressed a reluctant to socialize with others in a virtual environment. The notion of communicating virtually made them feel uncomfortable and participants preferred to socialize in the physical world (7 participants).

"I feel I'm comfortable, that I'd rather meet them in real life rather than as an avatar. Even though they might sound fine, I'd feel uncomfortable." (Participant 29, Female, 67)

One major concern with socializing in the virtual world was the possibility of avatars being used to give false representations or being used to deceive other users. This concern was reported by 13 of the participants.

"Well there are some difficulties, because you don't quite know if the avatars that you're meeting is anything like the person they are representing, so you have got snakes there.... they might be trying to give me the impression of such and such. If they could... they could give a false image of themselves, they could use their avatar in that way and you would have to be careful" (Participant 11, Male, 70).

The other barriers reported were related to the cognitive ability of older users. Cognitive load problems (Ang, Zaphiris, & Mahmood, 2007), difficulty in multi-tasking or the inability to give adequate concentration on a particular aspect of user interaction in the 3D virtual world due to cognitive requirements of other aspects (particularly navigation) were reported by six of the participants. Such problems have been reported to interfere with the participant's experience in the 3D virtual world. This was not surprising given the high cognitive load requirements in controlling their avatar, navigating to complete the task and communicating with their partner.

"Yes... I think the 3D was technically a problem... as you get older you find it more difficult to do multi- tasking..you find it more easier to do one thing... and particularly if you don't want mistakes.. so the 3D one makes it difficult because you have to direct someone and trying to choose the products... so you are doing two tasks at once... and you are also trying to relate to another person... it's more difficult.. I'm sure one task I could have done" (Participant 15, Male, 73).

Previous studies have shown how older users could have difficulty in navigating in a 3D space due to age related declines in cognitive ability (Sjolinder, Hook, Nilsson, & Andersson, 2005), (Sayers, 2004). Similar topics were also frequently mentioned by older participants in the interviews. 10 of the participants mentioned some form of difficulty in navigating through the 3D environment. Although some of the participants reported such problems were due to the difficulty in engaging with the control device (mouse and keyboard), factors related to spatial ability seem to be the main cause of this difficulty. For instance, 10 participants reported difficulty in locating and remembering the location of the items. Six participants also suggested they would feel more comfortable if they had a "map" or "store plan" which provides them with spatial information of their location and information of what was available in the store.

"Because I'm not used to using cursors and things on the computer. Also my memory, being 70 years old, just to remember where things were in the store wasn't good. You couldn't remember for example whether the frozen was left, baking or... I don't know I just couldn't remember it."

(Participant 11, Male,70).

"Things that you needed you couldn't find and when you decide that you wanted to find them you had to remember where they were. You had to go through the maze all over again" (Participant 9, Male, 74)

References of this lack of spatial awareness and the difficulty in navigation affecting physical presence and enjoyment have also been articulated during the interviews.

"I didn't know where I was most of the time. ....In the end, I found it seemed random. Just randomly walking around somewhere...but you know, it wasn't really fun.... It was too challenging" (Participant 7, Female, 61)

This supports the results from the regression analysis on the questionnaire data which found navigation to have a significant influence on physical presence and enjoyment.

7.3.4 Implications in the use of 3D virtual world technology

During the interviews, participants were asked to discuss the implications of using 3D virtual world technology. A number of suggestions such as how virtual worlds could be useful in travelling (giving virtual tours, giving directions etc, 5 participants) and healthcare (4 participants) were given. Three of the participants also felt that virtual worlds could be useful as a user-friendly interface for those who are not familiar with computers due to interaction in them being more natural.

Another interesting notion that was reported by six of the participants was that although they preferred to go out and do activities in the "physical" world, participants did see virtual worlds as being a useful alternative in case they became housebound or there were circumstances preventing them from leaving the house.

"I've got to get over that bridge...got to get over that because I don't want to be left out because I know that as I'm getting older, I'm going to be more housebound, and that would be my way of communicating and it would be nice" (Participant 28, Female, 62).

"I suppose if you were housebound, you could see a nurse or doctor that way...I mean they have already begun to bring technology into a user's home... it might be nicer if you saw someone like that" (Participant 34, Female, 67)

In regards to using virtual worlds for social interaction, the lack of transparency in avatar mediated communication (such as how the avatars can be used to give false impressions (discussed in section 7.3.3)) made some of the participants extremely reluctant to use virtual worlds to communicate with other users in a public social space (7 participants). However participants expressed more willingness to use virtual worlds to communicate with those who they already knew (such as family members or friends) and could confirm their identities.

"Participant 13: Then you get to our age it makes you how you are, and so I wouldn't be wanted to meet anybody [virtually]...

Interviewer: What about somebody you already knew, your friends, your family...?

Participant 13: Oh yes that would be better... but I would need convincing that it was actually them and no way could it be anyone else" (Participant 13 , Female, 67).

Including photos of their partners, even static ones have been suggested as a means to improve the level of transparency. This could help alleviate the fear of avatars being used in deception.

"If I was meeting up with a friend I'd much rather they have their own photograph on there or something" (Participant 12, Female, 58)

7.4 Conclusion and chapter implications

In this chapter, the results from a virtual store study where 38 older people were asked to carry out social interaction tasks in a 3D and non 3D virtual store were discussed. The main objective of this study was to analyze how aspects related to older users and the virtual world affect social interaction experience.

The key findings from this study could be summarized as follows:

- There was not a significant difference in the measures for the quality of social interaction experience between the non 3D and the 3D virtual stores.

- The results from the regression analysis show that the avatar does not directly influence the measures for the quality of social interaction. However, this factor has been found to influence physical presence which is a significant predictor of many of the quality of social interaction measures. Two key factors, the lack of non verbal communication and a difficulty in embodying physical people with virtual avatars have been reported to limit the usefulness of avatars in social interaction for older people.

- Navigation is also a key factor which influences the quality of social interaction. Regression analysis shows that apart from being a significant predictor of physical presence, navigation is also a significant predictor of performance, enjoyment and overall satisfaction. According to the interviews, cognitive problems (especially those related to spatial memory) were the main causes of difficulty in navigation.

- Physical presence was found to be a significant predictor in the majority of the measures for the quality of social interaction. This factor has been found to be a predictor of social presence, the quality of communication, overall satisfaction and enjoyment in the 3D virtual store. However, in the interviews, participants reported a sense of artificiality towards their experience, finding it difficult to immerse themselves in the virtual world. Similarity with the physical world was important to the participants and any perceived discrepancies made their experience feel less satisfying and less real. Participants also tended to associate their experience in the virtual world with playing a game.

- For the user factors, analysis of the questionnaire data found only past experience with computer games to be related to social presence. Older people also had a general mistrust towards CMC technology and were uncomfortable with using virtual worlds to carry out social interaction in a public space. Part of this was due to the concern of avatars being used to give false representations.

Overall, the findings in this study indicate a lack of difference in the social interaction experience between the non 3D store and 3D store. However, this should not be interpreted as virtual worlds not being able to provide a superior communication experience for older users. The study also identified a number of factors which could be addressed to improve the social interaction experience for older people in virtual worlds. For instance, adding facilities for non verbal communication and redesigning navigation in virtual worlds to minimize cognitive load could lead to a better 3D communication experience for older users. In section 8.3, a more in-depth discussion has been provided on how virtual worlds could be designed to better facilitate social interaction. It should also be noted that some of the participants were optimistic about some of the benefits of 3D virtual environments (as discussed in section 7.3.4) and this could indicate how useful such tools could become once these issues are addressed.

The main contribution of this study lies in the analysis of how the elements of the 3D virtual world and of older users themselves influence social interaction experience. Although, some of these elements have been investigated in past studies, this study examines them in the context of a fully functioning virtual world. For instance, past studies have evaluated the use of avatars as interfaces controlled by the computer to interact with older people (such as relational agents (Bickmore, Caruso, Clough-Gorr, & Heeren, 2005) and ambient intelligent devices interfaces (Oritz, A. et al, 2007)). In this study, the avatars were evaluated as entities controlled by older users which were used in an actual social interaction context in a 3D spatial environment. Studies investigating social interaction in this context usually focus on younger users (Vilhjálmsson, 2003). Therefore, the results from this study would help extend our understanding of how the concepts on social interaction in virtual worlds identified from these previous studies relate to older users.

7.5 Study Limitations

One limitation in this study is related to the limited sample size. This factor has a particular influence on the statistical analysis carried out in this study, especially on the Multiple-regression analysis with a large number of predictor variables. Cohen (1992) suggested that 38 samples are sufficient to detect a large effect (with a desired statistical power of 0.8 at a significant level of 0.05) for four predictor variables. Therefore, by using a small size, our model might fail to detect results of low and medium effect sizes (approximately 600 samples are required to detect small effect size for four predictor variables). Studies of such magnitude would be very difficult to carry out due to the specific nature of our participants. Future studies could compliment the findings in this study by carrying out within-subject controlled experiments and intentionally manipulating each of the factors to examine their effect on social interaction.

Chapter 8: Discussion

This thesis presents the results from a series of studies carried out to expand the knowledge on the use of 3D virtual worlds by older people. This chapter summarises and discusses the findings from these studies. More importantly, a set of guidelines derived from the findings are presented showing how virtual worlds could be better designed to facilitate social interaction (see section 8.3) and support healthy aging for older people (see section 8.4).

8.1 Older virtual world users

The first part of this thesis focuses on understanding the characteristics, interests and activities of older virtual world users. For this purpose, two studies were carried out. In the first study, interviews were carried out with older users from two virtual worlds (Chapter 3). In the second study, the profiles of older virtual world users were collected and analysed in comparison with those of younger users (Chapter 4). This section synthesises the results from both studies to provide an illustration of how older people use virtual worlds.

8.1.1 How do older people use virtual worlds and what are they interested in doing?

The findings from the two studies show a number of interests and activities of older people in the 3D virtual worlds. These activities are discussed in accordance to the three categories of user motivation proposed in section 2.6.5 (Social, Achievement and Immersion). Figure 34 provides a graphical summary.

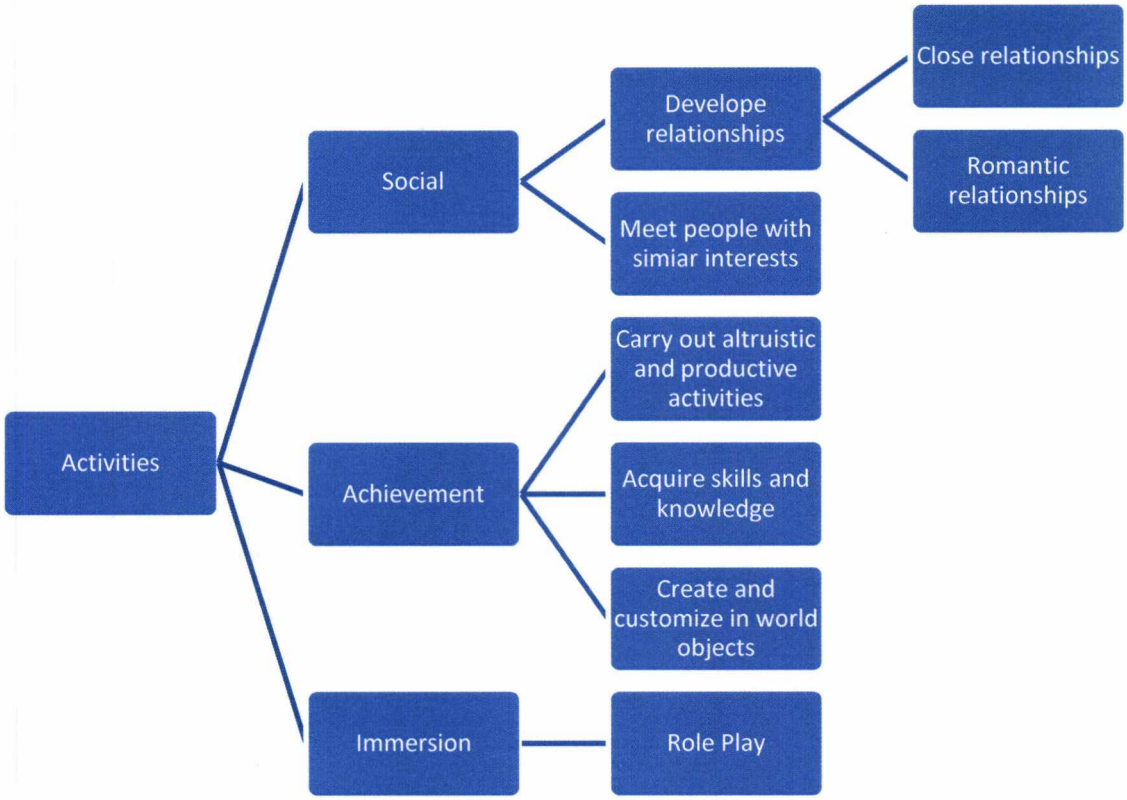


Figure 34: A diagram summarising the key interests and activities carried out by older people in virtual worlds

8.1.1.1 Social oriented activities

Social activities in virtual worlds include activities such as socializing with other users in the 3D virtual environment, developing relationships, friendships or using the virtual world to find a romantic partner (Zhou Z. , Jin, Vogel, Fang, & Chen, 2011). The findings from the two studies show a number of activities carried out by older virtual world users which fall into this category.

i) Developing social relationships

A common activity of older users in virtual worlds was to develop and maintain interpersonal relationships. The findings from the interviews suggested that these relationships were not only weak ties (as often found with young people on social network sites (Ellison, Steinfield, & Lampe, 2007)), but some were *close relationships* (section 3.3.2.1.1). The analysis of the social networks of older users in chapter 4 support this notion as the results show that although older users had fewer friends than younger users, they seem to have a high degree of interaction between each friend.

Even though other CMC technologies have been used in the same role ((Xie, 2008a), (Xie, 2008b), (Karavidas, Lim, & Katsikas, 2005), (Antikainen & Mittila, 2006) etc), the unique characteristics of virtual worlds (for instance, interactions being carried out in a 3D spatial context) could help enhance the process and benefits of relationship building. For instance, the diverse ways in which users could interact with each other (by carrying out a variety of social activities in an immersive 3D environment) and the embodiment and display of user interactions through avatars could allow online relationships to be developed and maintained more easily (Taylor T. L., 2002). The results also suggest that virtual worlds were able to act as a form of "Third Place" (see (Spence, 2008)) for older people, providing shared space outside the context of home and work for leisure and social interaction.

In addition, older people were interested in using virtual worlds to pursue *romantic relationships.* This is shown from the considerable number of older users who reported that they were looking for dating, those who reported having a "special person" and older users who joined "romance and dating" groups. The usage of virtual worlds for this purpose has also been frequently mentioned by older people during the interviews (section 3.3.2.1.1).

This is an interesting result which I believe is worth further exploring. Previous research investigating romantic relationships among older internet users suggested that contrary to popular stereotypes, long-term internet users in this age group were interested in using the internet to develop and foster romantic relationships (Malta, 2007). Examples of younger users developing similar romantic relationships have also been reported in virtual worlds such as Second Life (Boellstorff, 2008). A study even found that romantic relationships developed in this virtual world were more satisfying than those developed in real life (Gilbert, Murphy, & Avalos, 2011). This might explain the considerable interest of older users in pursuing romantic relationships in the virtual world. Further studies could be carried out to investigate the effect of the 3D environment and avatars in the development of romantic relationships for older users.

ii) Meeting and socializing with people who have similar interests

Analysis of the user group indicated that the most popular type of groups which older people joined was "shared interest groups", accounting for 23.5% of all the groups. This suggests that one popular usage of virtual worlds by older people is to meet and socialize with people who have similar interests. Other computer mediated communication technologies, especially online forums are used by older people for similar purposes (Wright, 2000), (Kanayama, 2003)). Similar to these technologies, virtual worlds help remove the limitations of physical space, extending the scope of possible relationships that can be formed and allow older users to meet a large number of people with circumstances and interests similar to their own (see sections 3.3.2.1.2 and 3.3.2.4.2).

8.1.1.2 Achievement oriented activities

Achievement oriented activities refer to activities which users carry out with the aim of enhancing their status in the virtual world (*in-world achievement*), activities carried out to enhance oneself in the physical world (such as improve skills or knowledge etc) or to address physical world needs which are utilitarian in nature (*physical world achievement*) (see section 2.6.5). The findings from the two studies give indication as to how older people have used virtual worlds to carry out activities related to both forms of achievement.

i) Carrying out activities which are altruistic and make useful contributions to society

One theme which was well reflected in both studies was related to how older people used virtual worlds to carry out activities which *made altruistic and useful contributions to society*. During the interviews, older users gave numerous examples of activities that they carried out in the virtual world which made productive contributions to others (see section 3.3.2.2.1). The altruistic nature of older users is also reflected by their gift-giving behaviour as older users who engaged in gift-giving gave significantly more gifts and showed higher levels of reciprocity than the typical younger user.

Bambrick and Bonder's study (2005) found that older people perceived productive activities as not only activities which generate economic value, but also those that are able to give back to the community. The study also reported that older people found a sense of fulfilment in carrying out volunteering activities. Okun et al (1998) found that older people were motivated to pursue such activities because of their personal values (concerns about people less fortunate them themselves etc) and because these activities helped enhance their self esteem. Volunteering activities could also provide a sense of usefulness and a meaningful social role in later life to compensate for roles loss due to aging (see (Onyx & Warburton, 2003) (Okun, Barr, & Herzog, 1998)). This could explain why older people were interested in carrying out altruistic activities and activities which made useful contributions to society in the virtual world.

In addition, this enthusiasm in using digital technology to make productive contributions to society might be considered a unique trait of older people as this enthusiasm could be found in other technologies apart from virtual worlds as well. Such enthusiasm can also be found in CMC technologies such as online support communities (Pfeil U. , 2010). Mittilä & Antikainen (2006) found activities of a similar nature (such as receiving and giving advice) to be one of the factors which attracted older people to online communities. Even studies investigating the design of computer games have reported "*contribution*" as a key passion which older people would like to see expressed through this technology (Abeele & Rompaey, 2006).

ii) Using virtual worlds to acquire skills and knowledge

Another achievement oriented activity of older users identified in the studies was the use of virtual worlds to acquire skills and knowledge. Analysis of the user groups show that older

users joined more groups related to learning than younger users (see section 4.2.3). Such activities were also reported by participants in the interview study. Older users were able to learn about programming by joining classes in the virtual world (section 3.3.2.2.3) and were able to acquire knowledge through informal avenues (such as being taught by other users) (section 3.3.2.3).

The interests of older people in using technology to improve their skills and abilities have also been reflected in other studies as well. Ijsselsteijn et al (2007) argue that one motivation older people have in engaging with digital games was to "sharpen one's mind". This might explain the growing popularity of many brain training games for users in this age group (Nouchi et al., 2012). Similarly, in Abeele & Rompaey's study (2006), apart from "contribution", "cultivation" was another concept in computer game design that was argued to provide a satisfying experience for older people. Recent trends also point to a growing interest and participation in online education courses among older people (especially those not able to participate in traditional onsite education courses) (Dorin, 2007). For example, online communities such as the University of Third Age Online (U3A online) have found considerable success in offering educational opportunities for older people in a social environment (Swindell, 2002). Similarly, the results from the studies in this thesis show that older users were also interested in pursuing activities in virtual worlds which helped enhance their knowledge.

iii) Creating and customising in-world objects

In regards to in-world achievement, one activity which older users were interested in was *creating and customising in-world objects.* Participants in the interview study reported investing time and energy in creating virtual items and then sharing them with their friends (see section 3.3.2.2.3). The results from the analysis of the user groups also support this finding as more older users were found to join groups related to creating virtual items (accounting for 9.6% of all groups) than the typical young user. Part of this interest could be due to the design and social culture in the virtual world which often encourages users to engage in object creation. Hayes (2006) argues that this social culture also creates a situated learning effect which encourages users to learn more about how to create better items, clothes and properties for their avatars. The findings from this thesis seem to support this argument as older people reported often having to find ways to learn more about specific techniques and technology to better create objects in the virtual world.

8.1.1.3 Immersion oriented activities

Immersion oriented activities refer to activities which users participate in mainly as a form of diversion or escape from their daily lives. In such activities, users rely on the immersive properties of the virtual worlds to submerge themselves in an alternative reality and act on a role set by the environment they are immersed in. Activities such as exploring and role-playing fall into this category (see section 2.6.5). Although such activities tend to be more popular with younger users, both studies in this thesis seem to indicate that some older users were also interested in these activities. Analysis of the user groups showed that older people

participated in a number of role-playing groups, such as ones where members role-play as characters in a medieval or fantasy society. Activities of a similar nature were also mentioned in the interview study. For instance, one user mentioned how he customized his land to mimic places from his favourite novels.

8.1.2 Characteristics of older virtual world users

A number of unique characteristics related to older people who used virtual worlds were also indentified. First, older virtual world users were those who were *receptive towards technology* (see section 3.3.2.2.3). As discussed earlier, part of this could be due to the situated learning effect from the social culture in the virtual world (users are motivated to learn more about advance computer skills to be able to engage more fully with other actors and the environment in the virtual world) (Hayes, 2006). A particularly encouraging finding from the interview study (chapter 3) was that some of these older users were those who had little technical experience prior to using the virtual world and became more interested in technology after engaging with virtual worlds. This suggests the possibility of virtual worlds being used as a catalyst to encourage older people to learn more about computers. Such knowledge could have various benefits to older people's well-being such as providing them with a sense of empowerment and independence (Shapira, Barak, & Gal, 2007). As the mechanisms for this are still unclear, more studies would need to be carried out to investigate this possibility.

The interviews also show how a number of older people who had *limitations in their mobility* in the physical world were motivated to use virtual worlds (section 3.3.2.4). Part of this could be due to the many benefits that virtual worlds could offer for them. For instance, virtual worlds could provide physically disabled users (who share many of the constraints and restrictions as older users limited in mobility) with social opportunities, a sense of self-esteem and emotional support (Stewart, Hansen, & Carey, 2010), (Ford, 2001). Case studies can also be seen where organizations such as "Virtual ability" in Second Life were able to provide such users with a supportive community and knowledge of how to use virtual worlds (Babiss, 2009). In addition, as discussed in section 3.3.2.4, virtual worlds could also help reduce the effect of their physical disabilities and allow them to engage in activities they are no longer able to do. Overall, the implications for older people in this domain are significant as people in this age group tend to suffer from similar restrictions and physical disabilities as they become older (Leitner & Leitner, 2004).

Overall, the results suggest that older people who use virtual worlds are perhaps typical older adults who have found virtual worlds beneficial in augmenting a part of their physical lives. For instance, the interest in using virtual worlds to develop social relationships or to meet with people who share similar interests suggest that older people use virtual worlds to address declines in their social relationship or feelings of loneliness. The interest in using virtual worlds to carry out altruistic activities or to learn new skills and knowledge could be a way to improve their self-esteem by bringing a sense of achievement. This could be done to compensate for the increasing need to be reliant on others or the loss in social power. Older

people who suffer from physical disabilities could also use virtual worlds to compensate for them, to carry out activities which would otherwise be difficult to carry out in the physical world. As discussed in section 2.1.1, many of these issues (the lowering of self esteem, loneliness etc) are common with transition into old age. Therefore, it is not surprising to see older people who are encountering these negative issues looking to use virtual worlds to compensate for them. In addition, it is not always older users who are technically adapt who engage with virtual worlds, as discussed in chapter 3, some participants had little experience with computers when they started using virtual worlds.

8.2 Social interaction in 3D virtual worlds for older people

After analyzing the results from the two studies carried out in the first part of the thesis, I found that social interaction was an important component in both the interaction of older people with virtual worlds and the activities which had potential to support healthy aging. Therefore, this topic became the main focus in the latter part of the thesis. Two experiment studies were carried out to investigate the social interaction of older people in virtual worlds using a virtual world system which was specifically developed for older users (chapters 5, 6 and 7).

The results from these studies showed that a number of factors related to older users influenced their social interaction experience. The first was related to the users' *prior experience with computer technologies.* In both studies, this factor was found to be related to the users' perception of presence (both physical and social). In the first study, when text was used as the main mode of communication (chapter 6), past experience with text messaging programs was found to be related to social and physical presence. However, when voice was used (chapter 7), past experience with 3D games was found to be related to physical and social presence. Part of this could be explained using the social information processing theory. Previous studies with text virtual worlds such as MUDs (Multi-user dungeons) have suggested that the more experience users have in communicating in this platform (which is mainly done using text), the more proficient they become in overcoming the limitations of text-based communication (Utz, 2000). This means that those who are not familiar with text communication could be less effective in expressing and reading emotions in a text based medium (For instance, users might not know how to use Emoticons) which could lead to less social presence. As voice communication is more natural (most users would already be familiar with this mode of communication), older users would already have learnt how to compensate for the limitations in this mode of communication. Therefore, prior experience in this domain would have less effect to presence than prior experience with 3D games.

Overall, *computer anxiety* was not found to have much impact on the measures for the quality of social interaction. Only in the first study which used text based communication was computer anxiety found to be related to the quality of communication. In the second study, computer anxiety was not found to be related to any of the quality of social interaction measures. However, in this study, *Psychological barriers* such as negative attitudes towards CMC technology were reported to effect social interaction experience. Other studies have

also reported similar factors affecting older people's use of computer technology (see (Wagner, Hassanein, & Head, 2010)). Older participants were particularly concerned about issues of deception and false identity. This seems to be a common fear of older people with CMC as such issues have been reported with other technologies such as web forums (Pfeil, Zaphiris, & Wilson, 2009) and social networking services (Lehtinen, Nasanen, & Sarvas, 2009). The use of a 3D avatar seems to further compound this problem, due to the possibility of people deliberately using avatars to misrepresent their identity. Suggestions on how such problems could be alleviated are provided in section 8.3.2.

Apart from factors related to older users themselves, factors related to the platform such as navigation, physical presence and the avatar were also found to influence social interaction experience. In both studies, *physical presence* was found to be related to many of the measures for the quality of social interaction. These results are in line with what is suggested in previous studies. For instance, physical presence has been argued to be related to enjoyment and social presence (see (Lombard & Ditton, 1997), (IJsselsteijn, Ridder, Freeman, & Avons, 2000)). Data from the interviews also suggest that some older people could have difficulty immersing themselves in the virtual world. Older people reported feeling that their experience in the virtual world was artificial and thought it was more similar to a game. Part of this perception could be due to participants' unfamiliarity with 3D virtual environments being used in other context apart from in computer games (which they have observed being used by their children or grand children). This perception could have negative implications if virtual worlds were to be used in a serious context for older people as potential users could hold a stereotype of virtual worlds being "just a game" and useful only for entertainment purposes. This might make it difficult for them to perceive the potential benefits of virtual worlds when they are used for serious activities.

Navigation was also found to be related to social presence and performance in both studies. In addition, this factor was found to be a significant predictor of physical presence. Previous research suggested that the degree of control users have of their interactions in the virtual world affects the perception of presence (Witmer & Singer, 1998), (Lombard & Ditton, 1997). As such, older people who had difficulty navigating in the virtual world might perceive a lack of control over their experience and thus report a lower level of presence. In addition, as older people are struggling with navigating around the virtual world, they might not be able to fully allocate their attention to immerse themselves with their surroundings. This could reduce their ability to perceive themselves as being inside the virtual world (Sacau, Laarni, & Hartmann, 2008).

The interviews from the study in chapter 7 suggest that the difficulties older people had in navigating were mainly due to cognitive related aspects. Prior studies have reported similar findings. For instance, one study found correlations between cognitive measures (such as visual memory, verbal memory) and navigation performance and found that older users made more spatial memory errors than younger users when engaging with a 3D environment (Moffat, Zondermana, & Resnicka, 2001). Another reason why older people have difficulty navigating could be related to difficulties in spatial learning. A number of studies have found

that older people had difficulty acquiring and using configural knowledge (an overall knowledge of the area and knowledge of where objects are in relation to each other) (see (Sjolinder, Hook, Nilsson, & Andersson, 2005)). Responses which reflected this notion were frequently made during the interviews. Participants often cited a lack of spatial awareness of their location and a difficulty in finding and remembering where objects were. Suggestions for reducing cognitive load in navigation have been provided in section 8.3.4.

The study in chapter 7 suggests that older people feel that *avatars* are of limited use in social interaction. Regression analysis showed that this factor was not a direct predictor of the measures for the quality of social interaction when the other factors (namely physical presence) were controlled. The results from the regression analysis seem to suggest that the usefulness of the avatars to social interaction was more as a placeholder for users in the virtual world (i.e. providing a sense of physical presence) and that the other aspects of the avatar (the remaining variance not explained by physical presence) had less impact on the quality of social interaction for older users.

One reason for the limited use of avatars in social interaction was that older people found it difficult to embody themselves and their partners with the avatars. According to Bartle's four levels of immersion, it would seem that older people in this study were only able to immerse themselves at the second level. Older users were able to perceive the avatars as being a *"representative"*, a puppet that they control, but do not perceive them as a *"representation"* or an extension of themselves and their personalities in the virtual world (Bartle, 2004). The interviews carried out in chapter 7 suggest that physical appearance, the lack of visible facial expression and a discrepancy between the audio communication and the visual avatars could be some of the causes of this lack of embodiment. Cheong et al (2011) who reported a similar finding with older users and static images of 3D avatars suggested that educational background (technical experience) and the lack of a background story were factors that caused older people to not be able to relate to the avatars.

Older people also found the lack of non verbal behaviour and facial expression to be another factor which limited the value of the avatar in social interaction. Not only did this factor reduce the level of realism, some even felt that this made it more difficult to trust their partners as many of the non verbal cues which could serve as indicators for deception (such as facial expression and body language) were not available when communicating in the 3D virtual world (Zuckerman & al, 1981). Much of this has also been reflected with other CMC technologies as well (Hancock, 2007). Previous studies related to social interaction in virtual environments also highlight the importance of non verbal cues in communication in this medium. For example, one study found that adding directed gaze to the avatars could help improve social presence (Garau, Slater, Vinayagamoorthy, Brogni, Steed, & Sasse, 2003). The results from the study in chapter 6 also emphasize the importance of non verbal cues for older people. In this study, older people were found to try to align their avatars at distances which resembled appropriate distances for interpersonal communication in the physical world when communicating in the virtual world.

8.3 How can social interaction be improved for older people in 3D virtual worlds

Based on the findings from both experiment studies, the following suggestions are provided to aid developers in designing virtual worlds that are better able to facilitate social interaction for older people.

8.3.1 Focusing first on nurturing small social networks and close relationships

Even though existing older virtual world users have reported success in expanding their network of friends through this platform, older people who are new to the concept of CMC and virtual worlds could find it difficult to accept the notion of socialising publicly with unacquainted partners (chapter 7). Analysis of the social networks of users also suggests that older users tend to develop fewer relationships but had higher levels of interaction with their friends (chapter 4). This suggests that older people could be more comfortable in using virtual worlds as a tool to build and maintain close relationships with a small network of known friends rather than to chat in a public space.

Drawing on this result, those looking to use virtual worlds to facilitate social interaction for older people could begin by assembling a small group of older people. The first activity which members carry out in the virtual world would be one which builds social rapport and helps them become more acquainted and at ease with each other. For instance, in open-ended virtual worlds such as Second Life, users could be encouraged to do a collaborative exercise such as constructing a building together (for example a virtual club house for their group). Later, the group could be taken on "field trip" activities and introduced to the various activities available in the virtual world (such as taken to a virtual museums etc). Introducing older people to virtual worlds in this manner would provide them with an established network of friends as they explore the other activities in the virtual world. This would help negate the initial fear of older people in having to develop relationships with unacquainted partners and the network of friends that they have already established could encourage them to continue to stay engaged with virtual worlds.

In addition, the findings suggest that mechanisms in virtual worlds which facilitate relationship building between small groups could be especially useful for older users. Many virtual worlds such as Second Life and IMVU contain mechanisms for user groups to be established. In chapter 3, I even identified a number of groups catering specifically to older users in one of these virtual worlds (section 3.1). These user groups could be especially useful as a means of fostering close relationships and connectivity, which could result in a more satisfying social experience for older users who join them. Asynchronous communication tools such as message boards could also be added to allow older users to keep in touch with fellow members of their group when they are not using the virtual world.

8.3.2 Providing mechanisms to ensure transparency in communication

One particular concern of older people in using virtual worlds for social interaction was related to the lack of transparency and the problems of online safety. One method to provide more transparency could be to build a profile page that contains photographs and accurate information about the users. Taking this a step further, photo-realistic avatar with similar characteristics to users could also be used. Such avatars could be created by mapping a user's photo with a 3D model customized to be similar in physical appearance to the actual user (see section 9.3.2 for further information about this process). These 3D avatars could provide older users with a source of identity without lowering perceived realism as a 2D photograph in a 3D virtual world might seem out of place. A preliminary study carried out with user interfaces using 2D photo-realistic avatars showed that older people preferred and accepted avatars which had faces they were familiar with (Morandell & al, 2008). A secondary benefit of using such avatars could be to allow older people to better relate the avatars to themselves and their partners, as older users reported difficulty in associating people with avatars whose virtual appearances did not match their physical world appearances.

However, care should be taken as introducing human avatars with high photorealism but with slight flaws could cause an "Uncanny Valley" effect. Researchers found that when the realism of a humanoid representation reaches a high enough level, they could invoke a sense of unpleasantness if they are perceived to have abnormal features (Seyama & Nagayama, 2007). One alternative could be to transform the avatars to be more "cartoon-like" but ensure that they retain enough similarities in physical appearance to be identifiable as the user. Another point to be considered when introducing such avatars is the impact this would have on anonymity. In chapter 3, older virtual world users have often cited the benefits of anonymity in avatar mediated interaction and cases of ageism have been reported when other users found out about their physical age. Introducing avatars with similar physical appearances to older users would remove the benefits of anonymity provided by the virtual world. More studies would need to be carried out to find the appropriate levels of photorealism and likeliness for such avatars to be useful for older people in virtual worlds.

8.3.3 Increasing social cues in virtual communication

The results from chapters 6 and 7 show the importance of non verbal cues in social interaction in the virtual world for older people. Most commercial virtual worlds existing at the time this thesis was written provide functions for expressing such cues (avatar gestures and facial expressions etc) either through an on-screen user interface (such as drop-down lists) or keyboard shortcuts. In some virtual worlds (particularly gaming virtual worlds such as World of Warcraft) users would have to use text base commands (such as type "/angry" in a command console to indicate an angry gesture). Even though this could provide a means to convey feelings and emotions which could help enrich social interaction, it would have less impact on issues of trust. As users could control when they want to express the gestures, their role as indicators of deception (Zuckerman & al, 1981) would still be somewhat limited.

Gesture based sensors (such as the Microsoft Kinect[30] or the Playstation Eye[31]) could be used to directly map a user's gesture onto their avatars during social interaction. The Microsoft Kinect in particular has the ability to detect facial expressions in addition to user gestures. Real-time mapping of these gestures would provide a more accurate representation of body language (particularly those displayed unconsciously). Using this technology could also help reduce the cognitive load of users when they are socializing as the gestures could be displayed automatically when detected. Section 9.3.1 provides more details on how this could be achieved.

Another method of enhancing non verbal communication could be to configure the view port on the user's screen to "zoom-in" onto the user and their partners' avatars when they are communicating. Subtle changes in facial expression could be hard to detect if the camera is too far from the avatars. By zooming the camera in, non-verbal communication would be more evident and older users could concentrate more on recognizing those gestures without being distracted by other factors. When users are conducting other activities (such as interacting with objects in the environment or navigating) the camera could be reverted to their original state.

8.3.4 Reducing cognitive load in navigation

Virtual worlds are complex environments which often place considerable overlapping demands on users for interaction (Ang, Zaphiris, & Mahmood, 2007). The complexity of one aspect of user interaction in the virtual world could have a profound impact on the overall social experience of users. Navigation is one activity that was found to place considerable demands on the cognitive load of older users.

In both experiment studies, navigation was shown to be related to many of the measures for the quality of social interaction. The interviews showed that older people had less difficulty with the mechanisms used to control the character, but more with spatial awareness and their ability to navigate to a find certain object (Chapter 7). Including 2D overhead maps could help improve a user's confidence when navigating (Sjolinder, Hook, Nilsson, & Andersson, 2005) but could also further increase cognitive load.

One possible solution is to considerably limit navigation in the virtual world. A case study of a virtual world which has adopted this strategy is IMVU. In this virtual world, users are only able to navigate to a set of pre-defined points in the virtual environment. This considerably eases the burden of navigating in the 3D environment and allows the user to focus more on social interaction. However, this could restrict the level of interactivity which could reduce perceived presence (IJsselsteijn, Ridder, Freeman, & Avons, 2000). Another possible solution is to create virtual environments based on physical world locations which older people are already familiar with. Mirror worlds (see (Metaverse Roadmap, 2007)) such as Twinity which

[30] www.xbox.com/en-GB/KINECT
[31] http://uk.playstation.com/ps3/peripherals/detail/item78698/PlayStation%C2%AEEye/

are created as virtual replicas of physical world locations could be used. Personalized virtual environments based on location well visited by users (such as a public park near their home etc) could also be used as a setting for social interaction. Such environments would allow older people to draw on existing configural knowledge without having to create new ones. This could help reduce the cognitive demands on navigation (Sjolinder, Hook, Nilsson, & Andersson, 2005).

8.4 Designing virtual worlds to support healthy aging for older people

The final part of this chapter discusses how virtual worlds could be better designed to support healthy aging. As explained earlier in section 2.2, healthy aging does not merely mean that one ages with a lack of disease but one must also be able to maintain a high cognitive function, have strong interpersonal relationships and be able to participate in productive activities (Rowe & Kahn, 1997). By analysing the findings from the various studies carried out in this thesis, a set of suggestions were produced to aid developers in creating better virtual environments to support healthy aging for older people. Examples of virtual world activities based on these suggestions were also given.

8.4.1 The inclusion of Social interaction in the activities designed to support healthy aging

Analysis of older virtual world users shows their strong interest in social activities. Therefore, the most direct implication of using virtual worlds to support healthy aging is to design virtual worlds to facilitate the development of interpersonal relationships. The social support obtained from these online relationships could have a positive impact on their health (Wright, 2000). Suggestions on how 3D virtual worlds could be designed to better facilitate social interaction for older users have been provided in section 8.3.

Even in activities designed to support the other dimensions of healthy aging (for instance to provide health information or facilitate productive activities), designers should include social interaction as a core component. The findings in chapters 3 and 4 highlight the importance of social interaction in such activities. For instance, older virtual world users were able to obtain knowledge about computers by being directly taught by other users or joining user groups related to learning about computers. The activities which provide productive contributions to society that were carried out by older users in the virtual world (such as teaching classes etc) also frequently involve a social element. The inclusion of social interaction in activities designed to support healthy aging could be an important factor which encourages older people to participate in them.

Examples of virtual world activities designed to support healthy aging that include social interaction as a key component are provided to give illustration:

- *Social activities for mental stimulation:* Mental stimulation and Cognitive training exercises have been used to help older people improve and maintain their cognitive abilities (Depp & Jeste, 2010). Social activities based on these exercises could be created in the virtual world. For instance, face name association is one exercise that has been used to train memory skills for older people. In this exercise, photos of people are shown to participants and they are asked to remember their names. Later, participants are shown the photos again and are asked to recall the names of the people in the photograph (Depp & Jeste, 2010). In one implementation of this exercise, participants are asked to imagine that they are working at a reception in a hotel and must greet guests whose names they have been asked to remember during check-in (Partner's consortium of MindWellness project, 2010). This exercise could be replicated in the virtual world. A virtual hotel reception area could be created and participants could role play as hotel staff and guests. The hotel staff would have to try to recall the names of the avatars of the guests as they are welcomed into the hotel.

  Another example is Reminiscence Therapy, an activity where older people are asked to recall memories and events in their past, sometimes with the help of visual and audio aids. This activity has been reported to help improve cognitive functioning and morale (Wang, 2007). Interactive computer tools have also been created to aid in this therapy (Gowans & al, 2004). Instead of using just videos and pictures, an immersive multi-user virtual environment reflecting a past event could be used to allow a group of older users to discuss their experiences related to the event together. The key advantage in using virtual environments in Reminiscence Therapy is the ease and low cost in which immersive experience could be created for older users.

- *Group discussions on issues related to health*: Virtual worlds could be used to facilitate small-scale group discussions on topics related to health. Healthcare support groups with topics catering specifically to older people (such as dementia) and staffed by healthcare professionals could be created and regular group discussions could be organized to provide health related knowledge to existing older users of virtual worlds. In addition, 3D virtual environments could be used to enhance existing online communities. Online communities such as Senior net have become popular with older people and the benefits such communities offer for them are well documented ((Kanayama, 2003), (Wright, 2000), (Pfeil U. , 2010)). In some instances, older people used this platform as an informal channel to exchange information and advice related to health (Pfeil U. , 2010). There are also a number of online forums focusing on specific health issues for older people which encourage this practice (such as the online forum of the Alzheimer's society[32], the senior health forum at Medhelp[33]). A small-scale 3D virtual environment could be introduced into these online communities to allow a group of forum members to meet in real time with each other and exchange advice and information related to health. X3D

[32] http://forum.alzheimers.org.uk/forum.php
[33] http://www.medhelp.org/forums/Senior-Health/show/141

technology[34] or Unity3D could be used to create a virtual environment which can be directly embed into the forum's webpage, further easing accessibility.

8.4.2 Designing virtual world activities with physical world implications

One recurring topic which was reflected in the studies carried out in this thesis was a strong emphasis on "realism" and activities with physical world implications as opposed to virtual ones. For instance:

- Compared to younger users, older users were more interested in joining groups to participate in activities which augmented their physical lives (chapter 4).

- A number of altruistic activities carried out by older virtual world users in chapter 3 had physical world implications (teaching classes, giving advice to others on issues related to their physical world lives etc.)

- Older people showed a strong preference for the "real" as opposed to the "virtual" (they preferred virtual activities which were based on physical world activities and avatars with appearances that were more similar to physical world characters etc). They also reported a sense of artificiality in their experience in the virtual world when they perceived any discrepancies between the virtual world and the physical world (chapter 5 and chapter 7).

- The analysis of proxemic behaviour in chapter 6 showed a tendency of older users to exhibit virtual behaviour that was more similar to physical world behaviour.

To reduce this sense of artificiality and appeal more to older users, healthy aging activities could be created to replicate activities which older people are already familiar with in the physical world. Leisure activities such as card games and scrabble have been associated with a decrease in the risk of dementia (Sharon, 2004). Such activities could be organized for older people in the virtual world. Presenting older people with activities they are familiar with and already understand the rules could help reduce the negative psychological barriers of engaging with an unknown technology. Such activities could also draw more interest from older people who are not normally interested in virtual worlds. For instance, one study found that older people were more interested in computer games that were based on activities they were familiar with such as sports (golf, yoga etc) or playing cards (Aison, Davis, Milner, & Targum, 2002). However, the main benefit of organizing such activities for older users is to allow those not normally able to participate due to physical world limitations to be able to do so in a virtual environment. Virtual worlds would therefore act as a kind of enabling technology in this context (Winder, 2008).

Virtual world activities designed to support healthy aging could also be constructed to emphasize more on providing physical world implications. For instance, virtual worlds could be used as a means of enhancing existing physical world activities which have positive effects

[34] http://www.web3d.org/realtime-3d/x3d/what-x3d

towards healthy aging. One example is the development of a virtual gallery. Visual arts have been argued to help improve care for older people with dementia (Basting, 2006). Care homes in the UK have reported success in using art activities (for instance paintings, photography) to help care for older people (The Baring Foundation, 2011). The virtual gallery could be used to showcase and share the works of art created by older people. The artworks created by older people in the physical world could be scanned and placed in this virtual gallery. Introducing an artefact which older people themselves created into the virtual world could help reduce the perceived artificiality of their experience.

Virtual worlds could also be used to provide opportunities for older people to learn more about an interest or hobby and to meet with individuals who share similar interests. An interactive learning community could be developed in the virtual world based on the online education model used by the University of the Third Age Online (U3A online). The U3A uses online technology such as E-mail and web forums to run interactive education courses for older people (Swindell, 2002). What is interesting about this model is that most of those who teach the courses are volunteers. As of 2012, the U3A offers more than 40 courses on topics ranging from Science to World affairs (U3A, 2012). Similar activities could be organized in virtual worlds. Learning in virtual environments has been argued to have many advantages such as the increased interactivity, immersion and social resources available (Johnson & Levine, 2008) (Warburton, 2009). A small interactive social space could be created as a meeting place and learning platform for older people who want to share an interest or learn more about a specific topic. Pre-customized virtual items based on the topic could be created for volunteers to use as props for teaching. The space could be created as a sort of "virtual sandbox". Such spaces could offer the dual benefit of promoting life-long learning and providing opportunities for social interaction, both of which have been argued to be important factors in healthy aging (Rowe & Kahn, 1997).

8.4.3 Providing opportunities for older people to make productive contributions to others

Analysis of the activities of older virtual world users show that they are interested in using virtual worlds to make productive contributions to society (section 8.1.1.2). Studies have shown that volunteering activities have a positive effect on the health of older people (Morrow-Howell & al, 2003) such as helping reduce depression (Musick & Wilson, 2003). Therefore, opportunities for altruism and contribution should be added to activities designed to support healthy aging.

Drawing on one example from chapter 3, virtual worlds could be used to allow older people to share experiences from their past careers through a mentor system. Young people who are at the start of their career could benefit from the advice given by these experienced retirees, while older people would be able to gain satisfaction and self esteem from tutoring the younger generation. Similar activities have been successfully carried out in the physical world. In one case, older professionals met with young entrepreneurs to offer knowledge and counselling in business management (Partner's consortium of MindWellness project, 2010).

The key advantage of replicating such activities in virtual worlds as opposed to other CMC tools is the ability to carry out actual training activities inside the 3D environment (Freitas, 2008). My own results show two case studies (section 3.3.2.2.1). In the first case study, a retired nurse gave a series of classes about child birth by using props and animated models which she developed herself in the virtual world. In the other, an older user had built, animated and programmed a number of virtual "dogs" and used them to teach others about dog training.

This mentoring system would not be limited to just young professionals, but could also be applied to young children as well. Intergenerational activities between the two age groups have been organized in care homes and were found to help improve both young children's perceptions towards aging as well as older people's well-being (de Souza, 2003). Older people could share their life experiences and knowledge with young children and in return could learn more about advances in new technologies from their partners. If appropriately designed, the game-like environment of virtual worlds could be especially appealing to young children.

From a design perspective, mechanisms which allow for simple acts of altruism could be added to the virtual world. Many virtual worlds have formal or informal methods for the gift-giving of virtual items. For instance, virtual worlds such as Second Life allow users to transfer items to others for free (Bakshy, Simmons, Huffaker, Teng, & Adamic, 2010). To facilitate such activities, a system could be created in which users receive free virtual items at certain intervals of their membership which they can give away to others. Reputation systems which are sometimes used in online forums could also be added to the virtual world (Lampel & Bhalla, 2007). In such systems, users would be allowed to "give points" to those who they found helpful. This mechanism could help provide a sense of status and achievement for those who make productive contributions to others.

8.5 Conclusion and chapter implications

In this chapter, the results from the studies carried out in the thesis are synthesized and discussed. The characteristics, interests and activities of older virtual world users were analyzed based on the findings from the studies in chapters 3 and 4. Overall, several activities of older virtual world users were identified in three categories: social, achievement and immersion. In addition, the results from the two experiments related to social interaction in chapters 6 and 7 were discussed and suggestions on designing better virtual worlds to facilitate social interaction were given. Finally, guidelines and examples on designing virtual worlds to better support healthy aging are given. The next chapter will provide a conclusion and discuss the implications of this thesis. At the end of that chapter, directions for future work are also provided.

Chapter 9: Conclusion

One of the key implications of the aging society that we are facing today is the need to find new and innovative ways to support older people as they age. One technology which could be beneficial in this domain is 3D virtual worlds. Virtual worlds incorporate many of the functionalities of technologies found to be beneficial in supporting older people (see section 2.5.4). In addition, many of the activities that are being carried out in virtual worlds have the potential to support healthy aging for older people in many areas (see section 2.5.5).

Developing and designing virtual worlds for older people is no easy task. There is a lack of research related to older people and 3D virtual environments. Despite a growing number of older people who are currently using virtual worlds, little is known about them and how they use this technology. More knowledge on how older people interact with virtual worlds would be essential before appropriate health supporting activities can be designed.

Through a series of studies, I have analyzed the interests and activities of older virtual world users. After identifying the importance of social interaction, I carried out two experiment studies, the first to determine age related differences in social interaction in virtual worlds and the second to investigate how different factors influence social interaction experience. The results from these two studies were then used to provide suggestions for improving social interaction for older people in virtual worlds. Finally, I discussed the design of virtual worlds and activities which could be used to support healthy aging.

9.1 Research questions addressed

Overall this thesis has addressed four research questions:

1. *What are the characteristics of older virtual world users and what activities do they carry out in virtual worlds?*

   This question was addressed from the exploratory interview study carried out in chapter 3 and the analysis of user profiles in chapter 4. The results show that older people who used virtual worlds were generally receptive towards technology and some had physical limitations which were compensated in virtual worlds. As for their activities and interests, older people developed interpersonal relationships (close friendships and romantic relationships) in virtual worlds and used this platform to meet and socialize with people who share similar interests. They were also interested in carry out activities which made useful contributions to society and activities which allowed them to acquire skills and knowledge.

2. *What are the age differences in user engagement (i.e. quality of social interaction, physical presence etc) and the display of non verbal behaviour in social interaction in the virtual world between older users and the typical young user?*

   This question was addressed from the virtual island study carried out in chapter 6. Significant differences were identified in regards to the perception of social presence. Older people perceived less social presence in the virtual world then their younger peers. In addition, older people found it harder to navigate in the virtual world. Different factors were found to be correlated with the quality of social interaction measures for older and younger people. Significant differences between older and younger people were also identified in regards to the display non verbal social behaviour. Older people seemed to exhibit proxemic behaviour in the virtual world which was more similar to the physical world when compared with younger people.

3. *What factors affect social interaction experience among older people in 3D virtual worlds and how could social interaction in virtual worlds be improved for older people?*

   This question was addressed mainly from the virtual store study carried out in chapter 7 and also in part from the virtual island study carried out in chapter 6. Factors such as navigation and physical presence were found to influence the quality of social interaction in 3D virtual worlds. The lack of non verbal cues and difficulty in associating avatars with physical people were found to limit the usefulness of the 3D avatars. Older people also had concerns about the possibility of avatars being used in deception. In addition, similarity with the physical world was also important. Based on these results, guidelines and suggestions on how virtual worlds could be designed to better facilitate social interaction for older people were proposed in section 8.3.

4. *How can effective activities that support healthy aging for older people be designed in virtual worlds?*

   The exploratory study in chapter 3 shows the potential value of virtual worlds in supporting healthy aging. By analyzing the results from the studies carried throughout this thesis, suggestions of how virtual worlds could be better designed to support healthy aging were provided along with examples of such activities (section 8.4).

9.2 Contributions

This thesis offers a number of contributions. First, there are theoretical contributions to existing literature such as identifying how older people use virtual worlds. There are also practical contributions such as the suggestions provided to help developers design better virtual worlds which support healthy aging and facilitate social interaction for older people.

Finally, this thesis provides a methodological contribution by showing how a 3D virtual world system could be developed and used to carry out experiment studies with older people.

9.2.1 Theoretical contributions

9.2.1.1 Providing an understanding of the characteristics, interactions and activities of older people in virtual worlds

As discussed in section 2.4.1, most research carried out to investigate computer use by older people focus on more traditional technologies such as online communities (such as (Pfeil, Zaphiris, & Wilson, 2009), (Kanayama, 2003)), e-mail (such as (Sayago & Blat, 2010)), the internet (such as (Eastman & Iyer, 2004) etc) and social network sites ((Lehtinen, Nasanen, & Sarvas, 2009), (Pfeil, Arjan, & Zaphiris, 2009)). Despite these technologies offering similar features as virtual worlds (see section 2.3), the combination of certain attributes (such as embodiment of user interactions through avatars, interactions being carried out in a 3D spatial environment) makes interaction in virtual worlds more unique when compared with other technologies. However, there have been few studies investigating older people's use of virtual worlds. Therefore, knowledge about how older people interact with virtual worlds would be a useful contribution to previous literature examining computer use among older people.

In addressing the first research question, this thesis has offered substantial contribution to help us understand how older people use and interact with 3D virtual worlds. The study in chapter 3 has provided us with an overview into the characteristics, interactions and activities of older virtual world users. Chapter 4 has provided empirical data to further extend our understanding in these topics. In addition, the analysis of the type of groups joined by older people in this chapter gives an indication of their interests in this platform, further extending the previous work on user motivation in 3D virtual environments (such as (Zhou Z. , Jin, Vogel, Xitong, & Chen, 2010) and (Yee, 2006)) in the context of older users.

Understanding how older people use and interact with virtual worlds would be the first step in designing virtual worlds which are able to interest and engage older users. Although virtual worlds are inherently complex systems that could pose significant barriers in accessibility for older users, previous studies have argued that older people are willing to learn to overcome these barriers if they perceive a technology to be useful (Czaja & Lee, 2007). Those seeking to use virtual worlds to provide education or healthcare could design their activities to incorporate elements which match the interests and preferences of older people. This could result in a wider participation of users from the old age group. In my case, I have applied this knowledge to design better virtual worlds (and virtual world activities) to support healthy aging (see section 8.4).

9.2.1.2 Extending the understanding of previously identified findings and concepts related to user interaction in virtual worlds in the context of older people

Most studies investigating user interaction with computer technologies, especially in the field of Human Computer interaction focus mainly on younger users (Dickinson, Arnott, & Prior, 2007). This is especially true for research related to 3D virtual environments (see section 2.6). In this thesis, a number of well explored concepts related to user interaction (such as physical presence, social presence etc) and behaviour in 3D virtual environments (proxemics etc) were examined, focusing on older users (Chapters 6 & 7).

The findings from this thesis contributes to the existing literature by extending our understanding of how these previously established concepts relate to older people. For instance:

- The findings in chapter 6 show significant age differences in the perception of social presence. In addition, significant age differences in the factors related to the perception of presence were also identified. This enhances the past work done related to presence in 3D virtual environments which usually focus on younger users (such as (Slater, Sadagic, & Usoh, 2000), etc).

- The findings related to age differences in navigational ability confirmed some of the findings from past studies related to older people's ability to navigate in a spatial 3D environment ((Sjolinder, Hook, Nilsson, & Andersson, 2005), (Moffat, Zondermana, & Resnicka, 2001)). This thesis also further shows how navigation could affect the user experience of older people in 3D virtual worlds (such as their perception of physical presence and their enjoyment).

- Other findings such as the effect of the avatars on social interaction experience and age differences in non verbal social behaviour also extends the results from past studies (such as (Cheong, Jung, & Theng, 2011), (Nowak & Biocca, 2003), (Smith, Farnham, & Steven, 2002), (Yee, Bailenson, Urbanek, Chang, & Merget, 2007) etc). For instance, this thesis shows the importance of non verbal cues in communication in a 3D virtual world for older people and discusses the reasons why older users had difficulty associating people with avatars.

9.2.2 Practical Contributions

9.2.2.1 Designing virtual worlds to support healthy aging for older people

This thesis also offers a number of practical contributions, the foremost being the guidelines to aid developers in designing better virtual worlds and virtual world activities to support healthy aging (section 8.4). Health practitioners could apply these findings to design activities in virtual worlds which are more effective in supporting older users.

In addition, by mapping the activities of older virtual word users with Rowe and Kahn's model of successful aging in chapter 3, a preliminary argument could be made as to how interaction in virtual worlds could potentially be beneficial in supporting healthy aging. This could be distinguished from previous studies looking to use virtual worlds to support older people. Most of these studies employ virtual worlds as part of a close-end system, usually to visualize information (Boers, Chodos, Huang, Gburzynski, Nikolaidis, & Stroulia, 2009), (Shaikh, Helmut, Hirose, & Mitsuru, 2009). Few studies have investigated how the interactions inside 3D desktop virtual worlds have the potential to support older people.

9.2.2.2 Improving social interaction for older people in virtual worlds

In section 8.3, a number of suggestions have been provided on how social interaction in 3D virtual worlds could be improved for older people. For instance, developers could focus first on nurturing small social networks and provide mechanisms to ensure transparency in communication.

These suggestions would be particularly useful for those seeking to use virtual worlds as a tool to facilitate social interaction for older people. As virtual worlds become more ubiquitous, they would also be used more frequently in the workplace and in education and training (Metaverse Roadmap, 2007). Because social interaction is a key component to many of these activities, the findings from this thesis could also be applied to make these activities more inclusive to older users.

9.2.3 Methodological Contributions

The inclusion of older people in experiment studies has been a key challenge for researchers investigating the use of computer technologies. Part of this is due to factors such as the lack of computer experience, reduced cognitive functionalities and mobility issues (Dickinson, Arnott, & Prior, 2007). This is especially true for research related to 3D virtual environments. Most studies of this nature require data to be collected from pre-established platforms with existing users (such as (Smith, Farnham, & Steven, 2002))

One methodological contribution of this thesis was the design and development of a virtual world system and experiment procedures to carry out studies with older people (chapter 5). I have shown how Unity3D could be used to create a virtual world system for carrying out experiment studies with older people, some of whom have little experience with computers. The design of this system and the experiment procedures were based on data gathered from a focus group study and the system was also refined through iterative testing. Researchers looking to create a virtual world system to use for testing with older people could apply similar principles in their design and development.

9.3 Future Work

This thesis aims to study the interactions of older people in 3D virtual environments and to apply those findings to design virtual worlds that are better able to support healthy aging. Due to the paucity of research in this area and the complex range of interactions existing with this technology, this thesis had to explore multiple factors together to identify key issues of importance (for instance in studying social interaction, factors such as navigation and the avatar were explored at the same time). This approach was adopted as it was difficult to determine beforehand which issues would be influential to older people's interactions in 3D virtual worlds.

As such, there are a number of limitations in this thesis which could be further investigated in future studies. Key examples include:

1. When investigating older virtual world users in chapters 3 and 4, methods such as semi-structured interviewing and quantitative analysis of user profiles were used. Different approaches such as ethnographic studies could be used to complement the findings in this study. In addition, the two virtual worlds selected in these studies were open-ended social virtual worlds, mainly due to the availability of older virtual world users. As discussed in Section 2.3, there are also other types of virtual worlds (such as gaming worlds etc). Future researchers could investigate the interactions of older users in these virtual worlds.

2. In chapter 7, a number of factors (such as navigational ability and physical presence) were found to influence the social interaction experience of older users. The findings from this chapter could be further validated by carrying out controlled experiments and manipulating each of these factors and testing them individually.

3. In the experiment studies carried out in chapters 6 and 7, most of the data was based on self reported responses from the participants. This is a common approach in studies measuring concepts such as presence, perceived satisfaction and performance ((Witmer & Singer, 1998), (Lombard & Ditton, 1997), (Suh, 1999)). Further studies could complement the findings in this study by using objective measures. For instance, devices such as electrocardiogram sensors could be used to measure physiological responses (Heart rate etc) which could be indicative of perceived presence (Baren & IJsselsteijn, 2004).

Finally, I propose some future directions for research, showing how the findings from this thesis could be extended.

9.3.1 The use of Natural user interfaces for gesture based social interaction

One potential area which could be investigated is the use of natural user interfaces for gesture based social interactions in virtual worlds. As seen in section 7.3.1.2, one limitation frequently mentioned by older people as they used virtual worlds for social interaction was

the lack of non verbal communication cues (such as hand gestures and facial expressions etc). Tools such as the Xbox Kinect[35] could be used to map the physical interactions of users to the avatars in the virtual world in real time. This would provide a more intuitive interface for displaying gestures and facial expressions. Rather than having to go through a list or a drop down menu to command the avatar to wave or smile, the kinect sensor could automatically detect them from the body positions of the users and display them through the avatars. Figure 35 shows a picture of the kinect sensor device and a simple test application developed using the kinect SDK[36] which detects the key body joints of the users.

Figure 35: A picture of the kinect sensor device (bottom) and a screenshot of a test application created using Visual C# (top). The top left screenshot shows the raw image captured from the kinect's video camera and the top right screenshot shows the joint position data captured from the kinect (The green circles indicate key joint positions (such as hands, face, neck, arms etc)).

Such a system could benefit older users in a number of ways. For instance, this intuitive mechanism in displaying gestures and facial expressions would enrich social interaction without causing too much cognitive load. A gesture based interaction system could also be implemented in which users could use gestures to intuitively control some of their actions in the virtual worlds (For instance, by reaching their hands out and doing a grabbing gesture to pick up products in the virtual supermarket). The use of gesture-based avatars has also been shown to be associated with positive changes in the perceptions of their partners (Ang, Bobrowicz, Siriaraya, Trickey, & Winspear, In press). However, many issues (such as the problem of concurrently navigating while displaying gestures) would still need to be resolved before this technology could be used efficiently.

[35] http://www.xbox.com/en-GB/KINECT

[36] http://www.microsoft.com/en-us/kinectforwindows/develop/developer-downloads.aspx

9.3.2 The use of customized avatars with physical appearances similar to users for social interaction

One of the limitations in avatar mediated communication which was identified was that older people found it difficult to embody themselves and associate their partners with the avatars (section 7.3.1.1). One reason given was that the visual appearances of the avatars did not match the true appearances of the users. Avatars with physical appearances similar to users could be created by using a 3D scanner to capture the physical appearance of the users and then converting them into 3D models (see Figure 36). These models could then be rigged, animated and imported into the virtual world.

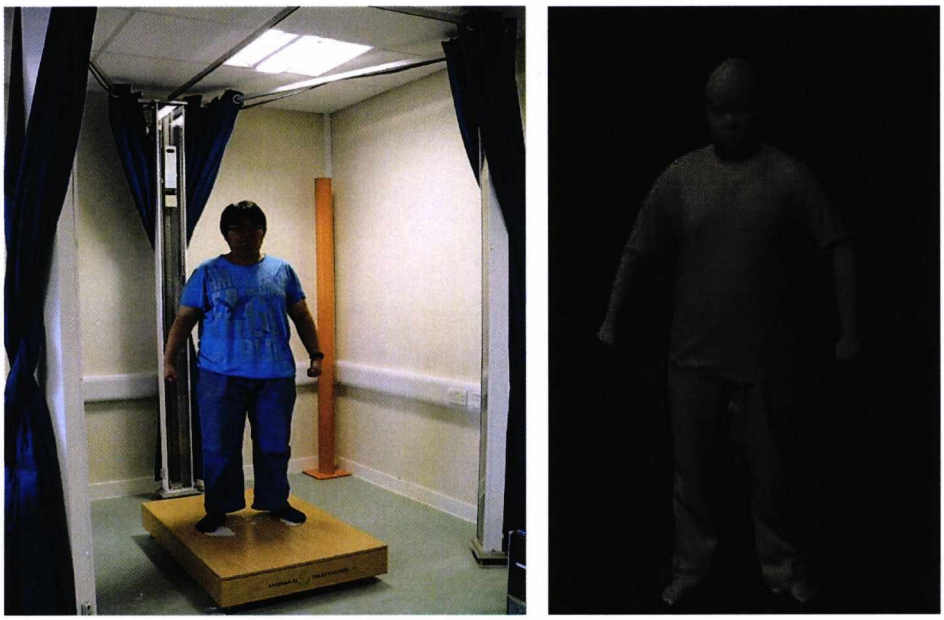


Figure 36: A picture of the 3D Scanner (left) and a screenshot of the non textured model scanned using the 3D scanner rendered from Maya (right).

Afterwards, controlled experiments could be carried out to study the impact of using such avatars in social interaction by comparing these avatars with more generic avatars. This would allow us to further understand the impact of using avatars with similar visual characteristics for social interaction.

As virtual worlds continue to grow and evolve, they could play an increasingly vital role in many domains in the near future. Already, examples are emerging of how virtual worlds are being used in education, communication, business and healthcare. Interactions in virtual worlds have many advantages. The immersive presentation of information in a 3D spatial environment and the wide range of interactions available could potentially lead to a more satisfying user experience.

Older people are one group of users who can greatly benefit from virtual worlds. The results from this thesis have shown how virtual worlds have empowered older people who have engaged with this technology. Older users benefited from opportunities in social engagement

and were able to cultivate their knowledge and make productive contributions to others through this platform. Many of these activities have the potential to be beneficial in supporting healthy aging. However, this thesis also shows that virtual worlds still possess many barriers for older people who are not familiar with the technology. Not all of these barriers were related to issues of usability. Some were related to how the designs of certain elements in the virtual worlds did not coincide with the interests and preferences of older people. Addressing these problems would be essential to encourage a wider participation of older people in this platform.

The work done in this thesis would provide a basis for future research related to older people and virtual worlds. Hopefully, this thesis would encourage more research to be carried out in this area. In addition, I am hopeful that the findings from the thesis would provide virtual world designers with ideas and concepts to create more engaging virtual worlds for older people, especially ones which are beneficial in supporting healthy aging.

References

Abdel-Khalek, A. M. (2006). Measuring happiness with a single-item scale. *social behaviour and personality, 34(2)* , 139-150.

Abeele, V. A., & Rompaey, V. (2006). Introducing human-centered research to game design: designing game concepts for and with senior citizens. *CHI2006 Conference on human factors in computing systems* (pp. 1469-1474). Montréal: ACM Press.

Aison, C., Davis, G., Milner, J., & Targum, E. (2002, May). *Appeal and Interest of Video Game Use Among the Elderly.* Retrieved May 25, 2012, from http://www.booizzy.com/jrmilner/portfolio/harvard/gameselderly.pdf

Ang, C. S., Bobrowicz, A., Siriaraya, P., Trickey, J., & Winspear, K. (In press). Effects of Gesture-based Avatar-mediated Communication on Brainstorming and Negotiation Tasks Among Younger Users. *Computers in Human Behavior* .

Ang, C. S., Zaphiris, P., & Mahmood, S. (2007). A model of cognitive loads in massively multiplayer online role playing games. *Interacting with Computers, 19(2)* , 167–179.

Antikainen, M., & Mittila, T. (2006). Perceived Attraction of Online Communities among Elderly People. *Frontiers of e-business research,November 28 - December 2.* Tampere, Finland.

Babiss, F. (2009). Heron Sanctuary. *Occupational Therapy in Mental Health 25(1)* , 1-3.

Bailenson, J. N., Beall, A. C., Loomis, J., Blascovich, J., & Turk, M. (2004). Transforming Social Interaction: Decoupling Representation from Behaviour and Form in collaborative Virtual Environments. *Presence 13(4)* , 428-441.

Bakshy, E., Simmons, M., Huffaker, D., Teng, C., & Adamic, L. (2010). The Social Dynamics of Economic Activity in a Virtual World. *Fourth International AAAI Conference on Weblogs and Social Media (ICWSM-10), May 23-26 2010.* Washington, DC.

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful ageing: the model of selective optimization with compensation. In P. B. Baltes, & M. M. Baltes, *Successful Ageing Perspectives From the Behavioural Sciences* (pp. 1-34). Cambridge,UK: Cambridge University Press.

Bambrick, P., & Bonder, B. (2005). Older adults' perceptions of work. *Work 24* , 77–84.

Baren, J. v., & IJsselsteijn, W. (2004, March 23). *Measuring Presence: A Guide to Current Measurement Approaches.* Retrieved 08 19, 2012, from OmniPres project IST-2001-39237: http://www8.informatik.umu.se/~jwworth/PresenceMeasurement.pdf

Bartle, R. A. (2004). *Designing virtual worlds.* Indianapolis, IN: New Riders.

Basting, A. D. (2006). Arts in Dementia Care: 'This is not the end... it's the end of this chapter.'. . *Generations 30(1)* , 16-20.

Becker, B., & Mark, G. (2002). Social Conventions in Computer-mediated Communications: A comparison of Three Online Shared Virtual Environments. In R. Schroeder, *The Social Life of Avatars* (pp. 19-39). Berlin: Springer.

Bell, M. W. (2008). *Toward a Definition of "Virtual Worlds".* Retrieved May 25, 2012, from Journal of Virtual Worlds Research 1(1): http://journals.tdl.org/jvwr/article/viewFile/283/237

Bente, G., & Kramer, N. C. (2011). Virtual gestures: embodiment and nonverbal behavior in computer-mediated communication. In A. Kappas, & N. C. Krämer, *Face-to-Face Communication over the Internet: Emotions in a Web of Culture, Language, and Technology* (pp. 176-210). Cambridge University Press.

Bickmore, T. W., Caruso, L., Clough-Gorr, K., & Heeren, T. (2005). 'It's just like you talk to a friend' relational agents for older adults. *Interacting with Computers 17(6)* , 711-735.

Biocca, F., Harms, C., & Burgoon, J. K. (2003). Towards a More Robust Theory and measure of social presence: Review and Suggested Criteria. *Presence 12(5)* , 456-480.

Blascovich, J. (2002). Social influence within immersive virtual environments. In R. Schroeder, *The social life of Avatars* (pp. 127-145). New York: Springer.

Bleacher, L. V., & Stockman, S. A. (2008). Second Life: A Venue for Informal Education and Participatory Exploration. *39th Lunar and Planetary Science Conference, (Lunar and Planetary Science XXXIX), March 10-14*, (p. 1167). League City, Texas.

Blit-Cohen, E., & Litwin, H. (2004). Elder participation in cyberspace: A qualitative analysis of Israeli retirees. *Journal of Aging studies 18(4)* , 385-398.

Blizzard Entertainment. (2008, Nov 21). *Blizzard Entertainment, Press Releases*. Retrieved 5 15, 2010, from World of warcraft subscriber base reaches 11.5 million worldwide: http://us.blizzard.com/en-us/company/press/pressreleases.html?081121

Boellstorff, T. (2008). *Coming of Age in Second Life.* Princeton University Press, Princeton.

Boers, N. M., Chodos, D., Huang, J., Gburzynski, P., Nikolaidis, I., & Stroulia, E. (2009). The smart condo: visualizing independent living environments in a virtual world. *3rd International Conference on Pervasive Computing Technologies for Healthcare,1-3 April 2009*, (pp. 1 - 8). London UK.

Boulos, M. N., Hetheringon, L., & Wheeler, S. (2007). Second Life: an overview of the potential of 3-D virtual worlds in medical and health education. *Health Information and Libraries Journals 24(4)* , 223-245.

Boulos, M. N., Ramloll, R., Jones, R., & Toth-Cohen, S. (2008). Web 3D for Public, Environmental and Occupational Health: Early Examples from Second Life®. *Int J Environ Res Public Health 5(4)* , 290-317.

Bowerman, B. L., & O'Connell, R. T. (1990). *Regression analysis; Linear models (Statistics)* . Boston: PWS-Kent Pub. Co.

Bowling, A. (2008). Enhancing later life: How older people perceive active ageing? *Aging & Mental Health 12(3)* , 293-301.

Bowling, A., & Dieppe, P. (2005). What is successful ageing and who should define it? *BMJ Volume 331(7531)* , 1548-1551.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology 3(2)* , 77-101.

Bryman, A. (2012). Mixed methods research: combining quantitative and qualitative research. In A. Bryman, *Social research methods: 4th edition* (pp. 627-652). Oxford, UK: Oxford University Press.

Bryman, A. (2008). *Social reseach methods; Third Edition.* New York: Oxford University Press Inc.

Bryman, A. (2004). *Social research methods; Second Edition.* New York: Oxford University Press.

Bryman, A., & Cramer, D. (2005). *Quantitative data analysis with SPSS 12 and 13.* Routledge: Routledge, Taylor and Francis Group.

Casanueva, J., & Blake, E. (2001). The effects of avatars on copresence in a collaborative virtual environment. *Technical Report CS01-02-00 TR. Cape Town, South Africa: Department of Computer Science, University of Cape Town* .

Castronova, E. (2005). *Synthetic worlds.* Chicago: The University of Chicago Press.

Castronova, E., & al, e. (2007). What Is A Synthetic World? In F. v. Borries, S. P. Walz, & B. Matthias, *Space Time Play : Computer Games, Architecture and Urbanism : The Next Level* (pp. 174-177). Basel, Berlin: Birkhauser Verlag AG.

Casual games discussion. (2007). *Future Play '07 Proceedings of the 2007 conference on Future Play, Toronto,Canada, November 15-17* (pp. 105-112). New York: ACM.

Cheong, W. L., Jung, Y., & Theng, Y.-L. (2011). Avatar: A virtual face for the elderly. *VRCAI*, (pp. 491-496). Hong Kong, China, December 11-12,2011.

Cohen, J. (1992). A power primer. *Psychological Bulletin 112(1)* , 155-159.

Creswell, J. W., & Clark, V. L. (2010). *Designing and Conducting Mixed Methods Research.* CA: Sage Publication.

Curtis, P. (1992). Mudding: Social Phenomena in Text-Based Virtual Realities. In P. Ludlow, *High noon on the electronic frontier: Conceptual issues in cyberspace* (pp. 347-374). Cambridge,Massachusetts : MIT Press.

Czaja, S., & Lee, C. C. (2007). Information technology and older adults. In J. Jacko, & A. Sears, *The Human–Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications* (pp. 778-792). New York: Erlbaum.

Darnton-Hill, I. (1995). Healthy aging and the qualitiy of life. *World health forum 16(4)* , 335-343.

de Souza, E. M. (2003). Intergenerational interaction in health promotion: a qualitative study in Brazil. *Rev. Saúde Pública 37(4)* , 463-469.

Depp, C. A., & Jeste, D. V. (2006). Definition and Predictors of Successful Aging: A Comprehensive Review of Larger quantitative studies. *American Journal of Geriatric Psychiatry 14(1)* , 6-20.

Depp, C. A., & Jeste, D. V. (2010). *Successful Cognitive and Emotional aging.* Arlington, VA: American Psychiatric Publishing, Inc.

Dickinson, A., & Hill, R. (2007). Educational Gerontology 33(8). *Keeping in touch: talking to older people aboutcomputers and communication* , 613-630.

Dickinson, A., Arnott, J., & Prior, S. (2007). Methods for human-computer interaction research with older people. *Behaviour and Information Technology 26(4)* , 343-352.

Dorin, M. (2007). Online education of older adults and its relation to life satisfaction. *Educational Gerontology 33(2)* , 127-143.

Dotsch, R., & Wigboldus, D. H. (2008). Virtual prejudice. *Journal of Experimental Social Psychology 44(4)* , 1194-1198.

Ducheneaut, N., Moore, J. R., & Nickell, E. (2004). Designing for sociability in Massively Multiplayer Games: an Examination of the "Third Places" of SWG. *Other Players conference, IT University of Copenhagen, 6-8 December 2004.* Copenhagen, Denmark.

Ducheneaut, N., Wen, M.-H. D., Yee, N., & Wadley, G. (2009). Body and Mind: A study of Avatar personalization in Three Virtual worlds. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2009, Boston, USA, April 4-9* (pp. 1151-1160). NY: ACM.

Ducheneaut, N., Yee, N., & al, e. (2006). "Alone Together?" Exploring the Social Dynamics of Massively Multiplayer Online Games. *Proceedings of the SIGCHI conference on Human Factors in computing systems, CHI 06, Montreal, Canada April 22 - 27, 2006* (pp. 407-416). New York: ACM.

Dyck, J. L., & Smither, J. A.-A. (1996). Older Adults' Acquisition of Word Processing: The Contribution of Cognitive Abilities and Computer Anxiety. *Computers in Human Behavior 12(1)* , 107–119.

Eastman, J. K., & Iyer, R. (2004). The elderly's uses and attitudes towards the Internet. *Journal of Consumer Marketing, 21(3)* , 208-220.

Ellis, R. D., & Allaire, J. C. (1999). Modeling Computer Interest in Older Adults: The Role of Age, Education, Computer Knowledge, and Computer Anxiety. *Human Factors: The Journal of the Human Factors and Ergonomics Society 41(3)* , 345-355.

Ellison, N. B., Steinfield, C., & Lampe, C. (2007). The Benefits of Facebook "Friends:" Social Capital and College Students' Use of Online Social Network Sites. *Journal of Computer-Mediated Communication,12(4)* , 1143-1168.

European Commission. (2007). *i2010 : independent living for the ageing society.* Luxembourg: Office for Official Publications of the European Communities.

Farris, M., Bates, R., Resnick, H., & Stabler, N. (1994). Evaluation of computer games' impact upon cognitively impaired frail elderly. *Computers in Human Services 11(1-2)* , 219–228.

Ferguson, C., & Nevell, P. (1996). The relationship between machine enjoyment, computer attitude and computer usage: some further refinements. *Accounting & Finance 36(1)* , 113-125.

Fetscherin, M., & Lattemann, C. (2008). User acceptance of virtual worlds. *Journal of Electronic Commerce Research 9(3)* , 231-242.

Field, A. (2005). *Discovering statistics using SPSS: Second Edition.* Oxford: Alden Press.

Field, A. (2009). *Discovering Statistics using SPSS: Third Edition.* London: Sage Publications .

Flynn, D., Schaik, P. V., Blackman, T., Femcott, C., Hobbs, B., & Calderon, C. (2003). Developing a virutal reality-based methodology for people with dementia: A Feasibility Study. *Cyberpsychology & Behaviour 6(6)* , 591-609.

Foo, C. Y., & Koivisto, E. M. (2004). Defining Grief Play in MMORPGs: Player and Developer. *Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology, Singapore, June 03 - 04, 2004* (pp. 245-250). New York: ACM.

Ford, P. J. (2001). Paralysis lost: impacts of virtual worlds on those with paralysis. *Social Theory and Practice 27(4)* , 661-680.

Fratiglioni, L., Paillard-Borg, S., & Winblad, B. (2004). An active and socially integrated lifestyle in late life might protect against dementia. *Lancet Neurol 3(6)* , 343–353.

Freitas, S. d. (2008). *Serious Virtual Worlds report.* Retrieved May 26, 2012, from http://www.jisc.ac.uk/media/documents/publications/seriousvirtualworldsv1.pdf

Freudenthal, D. (2001). Age differences in the performance of information retrieval tasks. *Behaviour and Information technology 20(1)* , 9-22.

Friedman, D., Steed, A., & Slater, M. (2007). Spatial Social Behavior in Second Life. *IVA '07 Proceedings of the 7th international conference on Intelligent Virtual Agents, Paris, France, September 17-19, 2007,.* Heidelberg: Springer-Verlag Berlin, .

Fron, J. e. (2007). Playing Dress-Up: Costumes, roleplay and imagination. *Philosophy of Computer Games, January 24-27 2007.* Italy.

Garau, M., Slater, M., Vinayagamoorthy, V., Brogni, A., Steed, A., & Sasse, A. (2003). The Impact of Avatar Realism and Eye Gaze Control on Perceived Quality of Communication in a Shared Immersive Virtual Environment. *CHI 2003,April 5–10.* Ft. Lauderdale, Florida, USA.

Getzel, G. S., & Mellor, M. J. (1985). Understanding normatve Growth and Development in Aging: Working with Strengths. In *Gerontological social work practice in the community* (pp. 37-54). Hew York: The Haworth Press Inc.

Gilbert, R., Murphy, N., & Avalos, M. (2011). Communication Patterns and Satisfaction Levels in Three-Dimensional Versus Real-Life Intimate Relationships. *Cyberpsychology, Behaviour and Social networking 14(10)* , 585-589.

Gowans, G., & al, e. (2004). Designing a Multimedia Conversation Aid for Reminiscence Therapy in Dementia Care Environments. *Design Case Study, 24-29 April*, (pp. 825-836). Vienna, Austria.

Griffiths, M. (2005). The therapeutic value of video games. In J. Raessens, & J. Goldstein, *Handbook of Computer Game Studies* (pp. 161-171). Cambridge: Mit Press.

Guadagno, R. E., Blascovich, J., Bailenson, J. N., & McCall, C. (2007). Virtual Humans and Persuasion:The Effects of Agency and Behavioral Realism. *Media Psychology 10(1)* , 1 - 22.

Gude, D. (2006). Navigation preferences and task performance in a web-based virtual environment. *Proc. of the 16th World Congress on Ergonomics, 10-14 July.* Maastricht, The Netherlands.

Gupta, K., & Steward, D. W. (1996). Customer Satisfaction and Customer Behavior: The Differential Role of Brand and Category Expectations. *Marketing Letters 7(3)* , 249-263.

Hall, E. T. (1966). *The hidden dimension* . London: The Bodley Head Ltd.

Hancock, J. T. (2007). Digital deception: When, where and how people lie online. In T. P. K. McKenna, *Oxford handbook of internet psychology* (pp. 287–301). Oxford: Oxford University Press.

Harris, H., & al, e. (2009). The Evolution of Social Behavior over Time in Second Life. *PRESENCE: Teleoperators & Virtual Environments 18(6)* , 434-448.

Hayes, E. R. (2006). Situated Learning in Virtual Worlds: The Learning Ecology of Second Life. *Adult Education Research Conference, 2006*, (pp. 154-159). http://www.adulterc.org/Proceedings/2006/Proceedings/Hayes.pdf.

Heiman, W. G. (2001). *Understanding research methods and statistics: An integrated introduction for psychology Second Edition.* Boston: Houghton Mifflin Company.

Heller, B., Wheat, J. S., Wright, P., & Mawson, S. (2008). Second Lives for the Third Age: Using virtual Worlds to Encourage Exercise Participation in Older People. *The Engineering of Sport 7* , 191-198.

Hinduja, S., & Patchin, J. W. (2008). Personal information of adolescents on the Internet: A quantitative content analysis of MySpace. *Journal of Adolescence 31(1)* , 125-146.

House, J., & Landis, K. (1988). Social relationships and health . *Science 29, Vol 241, Issue 4865* , 540-545.

IJsselsteijn, W. A., Ridder, H. d., Freeman, J., & Avons, S. (2000). Presence: Concept, determinants and measurement. *Proceedings of the SPIE, Human Vision and Electronic Imaging V, San Jose, California, January 24-27 2000* , 520–529.

Ijsselsteijn, W. N. (2007). Digital game design for elderly users. *Proceedings of the 2007 Conference on Future Play, November 15-17 2007, Toronto, Canada* , 17-22.

IMVU. (2011). *About IMVU*. Retrieved July 20, 2011, from IMVU: http://www.imvu.com/about/

Jeff Alstott, Ed Bullmore, Dietmar Plenz. (2013). powerlaw: a Python package for analysis of heavy-tailed distributions. arXiv:1305.0215

Jensen, L. J. (2009, January 18). *Editorial: Virtual conferences in Second Life*. Retrieved March 25, 2010, from http://larsjuhljensen.wordpress.com/2009/01/18/editorial-virtual-conferences-in-second-life/

Joffe, H., & Yardley, L. (2004). Content and thematic analysis. Research Methods for Clinical and Health Psychology . In D. Marks, & L. Yardley, *Research Methods for Clinical and Health Psychology* (pp. 56–68). London: Sage.

Johnson, L. F., & Levine, A. H. (2008). Virtual Worlds: Inherently Highly Social Learning Spaces. *Theory Into Practice 47(2)* , 161-170.

Jones, S., & Fox, S. (2009). *Generations Online in 2009.* Washington,DC: Pew Internet & American Life Project.

Jung et al. (2010). Low-income minority seniors' enrollment in a cybercafe : psychological barriers to crossing the digital divide. *Educational Gerontology 36(3)* , 193-212.

Jung, Y. (2011). Understanding the Role of the Sense of Presence and Percieved autonomy in User's Continued Use of social virtual worlds. *Journal of Computer-Mediated Communication 16(4)* , 492-510.

Jung, Y., & Kang, H. (2010). User goals in social virtual worlds: A means-end chain approach. *Computers in Human Behavior, 26(2)* , 218-225.

Kanayama, T. (2003). Ethnographic research on the experience of Japanese elderly people online. *New media and society 5(2)* , 267-286.

Kaplan, A. M., & Michael, H. (2009). The fairyland of Second Life: Virtual social worlds and how to use them. *Business Horizons Vol 52(6)* , 563—572.

Karahasanovic, A., & al, e. (2009). Co-creation and user-generated content- elderly people's user requirement. *Computers in Human Behaviour 25(3)* , 655-678.

Karavidas, M., Lim, N. K., & Katsikas, S. L. (2005). The effects of computers on older adult users. *Computers in Human Behaviour 21(5)* , 671-711.

Kizelshteyn, M. (2008). Therapy and The Metaverse: Second Life and The Changing Conditions of Therapy For Convalescent and Chronically Ill Users. *Washinton University Undergraduate Research digest 4 (1)* , 17-26.

Komter, A. E. (1996). Reciprocity as a principle of exclusion: Gift giving in the netherlands. *Sociology 30 (2)* , 299-316.

Kurniawan, S. and Zaphiris, P. 2005. Research-derived web design guidelines for older people. In *Proceedings of the 7th international ACM SIGACCESS conference on Computers and accessibility* (Assets '05). ACM, New York, NY, USA, 129-135. DOI=10.1145/1090785.1090810 http://doi.acm.org/10.1145/1090785.1090810

Lampel, J., & Bhalla, A. (2007). The Role of Status Seeking in Online Communities: Giving the Gift of Experience. *Journal of Computer-Mediated Communication 12(2)* , http://jcmc.indiana.edu/vol12/issue2/lampel.html.

Lee, B., Chen, Y., & Hewitt, L. (2011). Age differences in constraints encountered by seniors in their use of computers and the internet. *Computers in Human Behavior, 27(3)* , 1231-1237.

Lehtinen, V., Nasanen, J., & Sarvas, R. (2009). "A little silly and Empty-Headed" - Older adults understanding of social networking sites. *HCI-2009, People and Computers XXIII-Celebrating people and technology,1 - 5 September 2009,Churchill College Cambridge, UK* (pp. 45-54). Cambridge: The British Computer Society.

Leitner, M. J., & Leitner, S. F. (2004). *Lesuire in later life: Third edition.* New York: The Haworth Press, Inc.

Linden. (2010, January 19). *2009 End of Year Second Life Economy Wrap up*. Retrieved Febuary 4, 2010, from Second Life : https://blogs.secondlife.com/community/features/blog/2010/01/19/2009-end-of-year-second-life-economy-wrap-up-including-q4-economy-in-detail

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of computer mediated communication 3,(2)* , http://jcmc.indiana.edu/vol3/issue2/lombard.html.

Mahar, D., Henderson, R., & Deane, F. (1997). The effects of computer anxiety, state anxiety,and computer experience on users' performance of computer based tasks. *Personality and individual differences 22(5)* , 683-692.

Mallenius, S., Rossi, M., & Tuunainen, V. (2007). *Factors affecting the adoption and use of mobile devices and services by elderly people – results from a pilot study.* Retrieved June 18,

2012, from Proceeding of 6th Annual Global Mobility Roundtable, Los Angeles: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.130.2463&rep=rep1&type=pdf

Malta, S. (2007). Love Actually! Older Adults and their Romantic Internet Relationships. *Australian Journal of Emerging Technologies and Society 5(2)* , 84-102.

Mathur, A. (1996). Older Adults' Motivations for Gift Giving to Charitable Organizations: An Exchange Theory Perspective. *Psychology & Marketing 13(1)* , 107-123.

McGuire, F. A. (1986). *Computer technology and the aged: Implications and applications for activity programs.* New York: The Haworth Press.

Medlock, M. C., Wixon, D., Terrano, M., Romero, R. L., & Fulton, B. (2002). *Using the RITE method to improve products; a definition and a case study.* Usability Professionals Association.

Melenhorst, A. S., Rogers, W. A., & Bouwhuis, D. G. (2006). Older Adults' Motivated Choice for Technological Innovation: Evidence for Benefit-Driven Selectivity. *Psychology and Aging 21(1)* , 190-195.

Metaverse Roadmap. (2007). *Metaverse Roadmap: Industry Conditions*. Retrieved January 2, 2010, from Metaverse Roadmap Pathway to the 3D web: http://metaverseroadmap.org/inputs.html#history

metaversum. (2010). *Twinity Glossary Page*. Retrieved Jan 8, 2010, from Twinity : http://www.twinity.com/en/glossary

Midlarsky, E., & Hannah, M. E. (1989). The generous elderly: Naturalistic studies of donations across the life span. *Psychology and Aging 4(3)* , 346-351.

Mislove, A., Marcon, M., Gummadi, K. P., Druschel, P., & Bhattacharjee, B. (2007, October). Measurement and analysis of online social networks. In *Proceedings of the 7th ACM SIGCOMM conference on Internet measurement* (pp. 29-42). ACM.

Moffat, S. D., Zondermana, A. B., & Resnicka, S. M. (2001). Age differences in spatial memory in a virtual environment navigation task. *Neurobiology of Aging 22(5)* , 787-796.

Mollick, E., & Edery, D. (2008). *Changing the Game: How Video Games Are Transforming the Future of Business: How Video Games Are Transforming the Business World* . New Jersey: Financial Times.

Morandell, M. M., Hochgatterer, A., Fagel, S., & Wassertheurer, S. (2008). Avatars in Assistive Homes for the Elderly A User-Friendly Way of interaction? *HCI and Usability for Education and Work, Vol(5298)* , 391-402.

Morningstar, C., Farmer, F. R., & Researchers, I. (2008). The Lessons of Lucasfilm's Habitat. *Journal of virtual worlds research 1(1)* , 1-21. https://journals.tdl.org/jvwr/article/viewFile/287/241.

Morrow-Howell, N., & al, e. (2003). Effects of Volunteering on the Well-Being of Older adults. *Journal of Gerontology 58B (3)* , S137–S145.

Musick, M. A., & Wilson, J. (2003). Volunteering and depression: the role of psychological and social resources in different age groups. *Social Science & Medicine 56(2)* , 259-269.

Newell A. F. 2008. Accessible computing – Past trends and future suggestions. ACM Trans. Access. Comput. 1, 2, Article 9 (October 2008), 7 pages. DOI = 10.1145 /1408760.1408763. http://doi.acm.org/10.1145/1408760.1408763.

Newell, A. F., & Gregor, P. (2000, November). "User sensitive inclusive design"—in search of a new paradigm. In *Proceedings on the 2000 conference on Universal Usability* (pp. 39-44). ACM.

Norris, J. (2009). The Growth and Direction of Heathcare Support Groups in Virtual worlds. *Journal of Virtual Worlds Research 2(2)* , https://journals.tdl.org/jvwr/article/view/658/500.

Nouchi et al. (2012). Brain Training Game Improves Executive Functions and Processing Speed in the Elderly: A Randomized Controlled Trial. *PloS One, 7 (1)* , http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0029676.

Nowak, K. L., & Biocca, F. (2003). The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments. *Presence: Teleoperators and virtual environments 12(5)* , 481-494.

Nowak, K. L., & Rauh, C. (2006). The influence of the avatar on Online percerptions of Anthropomorphsim, Androgyny, Credibility, Homophily and Attraction. *Journal of Computer-Mediated Communication 11(1)* , 153-178.

Okun, M. A., Barr, A., & Herzog, R. A. (1998). Motivation to Volunteer by Older Adults:. *Psychology and Aging 13(4)* , 608-621.

Onyx, J., & Warburton, J. (2003). Volunteering and health among older people: a review. *Australasian Journal on Ageing 22(2)* , 65-69.

Oritz, A. et al. (2007). Elderly Users in Ambient Intelligence: Does an Avatar Improve the Interaction? *Lecture notes in computer science (4397)* , 99-116.

Ostrander, M. (2008). Talking, looking, flying, searching: information seeking behaviour in Second Life. *Library Hi Tech 26(4)* , 512 - 524.

Partner's consortium of MindWellness project. (2010). *Handbook on Brain Training for older people.* EACEA.

Peacock, S. E., & Ku¨nemund, H. (2007). Senior citizens and Internet technology: Reasons and correlates of access versus non-access in a European comparitive perspective. *European Journal of Aging 4(4)* , 191-200.

Pew Research Center. (2010a). *Generations 2010.* Retrieved 08 26, 2011, from http://pewinternet.org/Reports/2010/Generations-2010.aspx

Pew Research Center. (2010b). *Older Adults and Social Media.* Retrieved 08 26, 2011, from http://pewinternet.org/Reports/2010/Older-Adults-and-Social-Media.aspx

Pfeil, U. (2009). Older adults' perceptions and experiences of online social support. *Interacting with computers 21(3)* , 159-172.

Pfeil, U. (2010). Online support communities. In C. S. Ang, & P. Zaphiris, *Social computing and virtual communities* (pp. 121-150). FL: Taylor & Francis Group.

Pfeil, U., & Zaphiris, P. (2007). Patterns of empathy in online communication. *CHI '07 Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 919-928). ACM.

Pfeil, U., Ang, C. S., & Zaphiris, P. (2009). Issues and Challenges of Teaching and Learning in 3D virtual worlds: Real Life Case Studies. *Journal of Educational Media International 40(30)* , 223-238.

Pfeil, U., Arjan, R., & Zaphiris, P. (2009). Age differences in online social networking- A study of user profiles and the social capital divide among teenagers and older users in MySpace. *Computers in Human Behavior 25(3)* , 643-654.

Pfeil, U., Zaphiris, P., & Wilson, S. (2009). Older adults' perceptions and experiences of online socialsupport. *Interacting with Computers 21(3)* , 159–172.

Phang, C. W., Sutanto, J., Kankanhalli, A., Li, Y., Tan, B. C., & Teo, H. H. (2006). Senior Citizens' Acceptance of Information Systems: A Study in the Context of e-Government Services. *IEEE transactions on engineering management 53(4)* , 555-569.

Pullin, G., & Newell, A. (2007). Focussing on extra-ordinary users. In *Universal Acess in Human Computer Interaction. Coping with Diversity* (pp. 253-262). Springer Berlin Heidelberg.

Robins, R. W., Trzesniewski, K. H., Tracy, J. L., Gosling, S. D., & Potter, J. (2002). Global self-esteem across the life span. *Psychology and aging*, 17(3), 423-434.

Rook, K. S. (1987). Social support versus companionship: Effects on life stress, loneliness, and evaluations by others. *Journal of Personality and Social Psychology 52(6)* , 1132-1147.

Rowe, J. W., & Kahn, R. L. (1987). Human Aging: Usual and Successful. *Science 237(4811)* , 143-149.

Rowe, J. W., & Kahn, R. L. (1997). Succesful Aging. *The Gerontologist 37(4)* , 433-440.

Roy, N., & al, e. (2000). Towards Personal Service Robots for the Elderly. *Proc. of the Workshop on Interactive Robotics and Entertainment (30 April 2000- 1 May 2000), Pennsylvania USA* .

Ryu, ,. M., Kim, S., & Lee, E. (2009). Understanding the factors affecting online elderly user's participation in video UCC. *Computers in Human Behavior 25(3)* , 619-632.

Sacau, A., Laarni, J., & Hartmann, T. (2008). Influence of individual factors on presence. *Computers in Human Behavior 24(5)* , 2255–2273.

Sayago, S., & Blat, J. (2010). Telling the story of older people e-mailing: An ethnographical study. *International Journal of Human-Computer Studies 68(1)* , 105-120.

Sayers, H. (2004). Desktop virtual environments: a study of navigation and age. *Interacting with Computers 16(5)* , 939–956.

Second Life History. (2012). Retrieved July 5, 2012, from Second Life: http://wiki.secondlife.com/wiki/History

Seyama, J., & Nagayama, R. S. (2007). The Uncanny Valley: Effect of Realism on the Impression of Artificial Human Faces. *Presence: Teleoperators & Virtual Environments, 16(4)* , 337-351.

Shaikh, M. A., Helmut, P., Hirose, K., & Mitsuru, I. (2009). Easy Living in the Virtual World: A Novel Approach to Integrate Real World. *IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology, 15-18 Sept 2009*, (pp. 466-473). Milan, Italy.

Shapira, N., Barak, A., & Gal, I. (2007). Promoting older adults' well-being through Internet training and use. *Aging & Mental Health 11(5)* , 477–484.

Sharon, B. K. (2004). Leisure activity and risk of dementia scrabble, anyone? *Can Fam Physician,50 (January)* , 51–53.

Short, J., Ederyn, W., & Bruce, C. (1976). *The social psychology of telecommunications.* London and New York: Wiley.

Simon, A. F. (2006). Computer-Mediated Communication: Task Performance and Satisfaction. *The Journal of Social Psychology 146(3)* , 349-379.

Singh, A., & Misra, N. (2009). Loneliness, depression and sociability in old age. Industrial psychiatry journal, 18(1), 51.

Siriaraya, P., & Ang, C. S. (2012a). Characteristics and usage patterns of older people in a 3D online multi-user virtual environment. *Computers in Human Behavior, 28(5)* , 1873-1882.

Siriaraya, P., & Ang, C. S. (2012b). Age differences in the perception of social presence in the use of 3D virtual world for social interaction. *Special Issue on presence and interaction, Interacting with Computers 24* , 280-291.

Siriaraya, P., Ang, C. S., & Bobrowicz, A. (in press). Exploring the potential of virtual worlds in engaging older people and supporting healthy aging. *Behaviour & Information Technology* .

Sivan, Y. (2008). 3D3C Real Virtual Worlds Defined: The Immense Potential of Merging 3D, Community, Creation, and Commerce. . *Journal of virtual world research 1(1)* , http://journals.tdl.org/jvwr/article/view/278/234.

Sjölinder, M., Höök, K., & Nilsson, L. G. (2000). Age difference in the use of an on-line grocery shop: implications for design. *CHI EA '00 CHI '00 Extended Abstracts on Human Factors in Computing Systems* (pp. 135-136). New York, NY: ACM.

Sjolinder, M., Hook, K., Nilsson, L.-G., & Andersson, G. (2005). Age differences and the acquisition of spatial knowledge in a three-dimensional environment: Evaluating the use of an overview map as a navigation aid. *International Journal of Human-Computer Studies 63(6)* , 537-564.

Slater, M., & Steed, A. (2002). Meeting people Virtually: Experiments in Shared Virtual Environments. In R. Schroeder, *The Social Life of Avatars* (pp. 146-171). London: Springer.

Slater, M., Sadagic, A., & Usoh, M. (2000). Small group behaviour in a virtual and real environment: A comparitive study. *Presence 9(1)* , 37-51.

Slater, M., Steed, A., & Usoh, M. (1994). Depth of presence in virtual environments. *Presence 3(2)* , 130-144.

Smith, M. A., Farnham, S. D., & Steven, D. M. (2002). The Social Life of Small Graphical Chat Spaces. In R. Schroeder, *The social life of Avatars: presence and interaction in shared virtual environments* (pp. 205-219). London: Springer.

Spence, J. (2008). *Demographics of virtual worlds.* Retrieved July 19, 2011, from Journal of Virtual Worlds Research 1(2): http://journals.tdl.org/jvwr/article/view/360/272

Stanney, K. M., Mourant, R. R., & Kennedy, R. S. (1998). Human factors Issues in Virtual Environments: A review of literature. *Presence 7(4)* , 327-350.

Steinkuehler, C. A., & Williams, D. (2006). Where Everybody Knows Your (Screen) Name: Online Games as ''Third Places''. *Journal of Computer-Mediated Communication 11(4)* , 885–909.

Stewart, S., Hansen, T. S., & Carey, T. A. (2010). Opportunities for People with Disabilities in the Virtual World of Second Life. *Rehabilitation Nursing 35(6)* , 254-259.

Suh, K. S. (1999). Impact of communication medium on task performance and satisfaction: an examination of media-richness theory. *Information & Management 35(5)* , 295-312.

Swindell, R. (2002). U3A Online: a virtual University of the Third Age for isolated older people. *International Journal of Lifelong Education 21(5)* , 414-429.

Tan, D. S., Robertson, G. G., & Czerwinski, M. (2001). Exploring 3D Navigation: Combining Speed-coupled Flying with Orbiting. *Proceedings of the SIGCHI conference on Human factors in computer systems, Seattle, Washington, USA, March 31- April 5,* (pp. 418-425). ACM.

Taylor, T. L. (2002). Living Digitally: Embodiment in Virtual Worlds. In R. Schroeder, *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments.* (pp. 40-62). London: Springer-Verlag.

Taylor, T. L. (2006). *Play Between Worlds: Exploring Online Game.* MIT Press, Cambridge, MA.

The Baring Foundation. (2011). *Creative Homes: How the arts can contribute to quality of life in residental care.* London: The Baring Foundation.

The Second life Survey. (2007, August 31). *Demography*. Retrieved November 14, 2010, from SL Survey: Residents profile, gambling & engagement: http://slsurvey.wordpress.com/survey-result/demography/

Thelwall, M. (2008). Social networks, Gender and Friendling: An analysis of MySpace Member Profiles. *Journal of the american society for information science and technology 58(9)* , 1321-1330.

U3A. (2012). *Courses*. Retrieved 10 15, 2012, from U3A online: http://www.u3aonline.org.au/u3a/courses/

UN . (2007). *UN population report, Executive Summary, 2007 edition of World Population Ageing.* United Nations Department of Economic and Social Affairs, Population Division.

UNECE. (2009). *Policy Brief: Older persons as consumers.* UNECE.

Urban, R. (2007). A Second Life for Your Museum: 3D Multi-User Virtual Environments and Museums. *Museums and the Web 2007.* (p. http://www.archimuse.com/mw2007/papers/urban/urban.html). Toronto: Archives & Museum Informatics.

US Census Bureau. (2009, 06 23). *Census Bureau Reports World's Older Population*. Retrieved 03 16, 2010, from US Census Bureau: http://www.census.gov/Press-Release/www/releases/archives/international_population/013882.html

US Census Bureau. (2011). *America's Families and Living Arrangements: 2011*. Retrieved 24 05, 2013, from US Census Bureau: http:// www.census.gov/population/www/socdemo/hh-fam/cps2011.html

Utz, S. (2000). *Social information processing in MUDs: The Development of Friendships in Virtual worlds.* Retrieved May 27, 2012, from Journal of Online Behaviour 1(1): http://www.behavior.net/job/v1n1/utz.html

Vilhjálmsson, H. (2003). Avatar Augmented Online Conversation. Ph.D. thesis, MIT Media Lab.

Vincent, J. (2003). *Old Age (Key Ideas).* New York, USA: Routledge.

Wagner, N., Hassanein, K., & Head, M. (2010). Computer use by older adults: A multi-disciplinary review. *Computers in Human Behavior 26(5)* , 870-882.

Wang, J.-J. (2007). Group reminiscence therapy for cognitive and affective function of demented elderly in Taiwan. *International Journal of Geriatric Psychiatry 22(12)* , 1235-1240.

Wanous, J. P., Reichers, A. E., & Hudy, M. J. (1997). Overall Job Satisfaction: How good are single-Item Measures? *Journal of Applied Psychology 82(2)* , 247-252.

Warburton, S. (2009). Second Life in higher education: Assessing the potential for and the barriers to deploying virtual worlds in learning and teaching. *British Journal of Educational Technology 40(3)* , 414-426.

Watering, M. (2005). *The Impact of Computer Technology on the Elderly.* Retrieved 10 22, 2012, from http://www.marekvandewatering.com/texts/HCI_Essay_Marek_van_de_Watering.pdf

Winder, D. (2008). *Being Virtual, who you really are online.* UK: John Wiley & Sons Ltd.

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J. Ravaja, N., Gouveia, F.R., Biocca, F. , Sacau A., Jancke, L., Baumgartner,T. & Jäncke, P. (2007). A process model of the formation of spatial presence experiences. *Media Psychology, 9*(3), 493-525.

Wirtz, S., Jakobs, E. M., & Ziefle, M. (2009). Age-specific usability issues of software interfaces. In Proceedings of the IEA.

Wischnowsky, D. (2007, Feb 16). *Wii bowling knocks over retirement home*. Retrieved May 30, 2009, from chicago tribune Online: http://www.chicagotribune.com/news/local/chi-070216nintendo,0,2755896.story

Witmer, B. G., & Singer, J. M. (1998). Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence 7(3)* , 225-240.

Wong, Y. (2006). *The glittering silver market: the rise of elderly consumers in Asia.* Singapore: Wiley.

World health Organisation. (2010, Dec 08). *Definition of an older or elderly person*. Retrieved Jan 26, 2011, from World Health organisation: http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html

Wright, K. (2000). Computer-mediated social support, Older adults and coping. *Journal of Communication 50(3)* , 110-118.

Xie, B. (2008a). *The mutual shaping of online and offline social relationships*. Retrieved 2012 27-05 from Information Research 13(3): http://eric.ed.gov/PDFS/EJ837272.pdf

Xie, B. (2008b). Multimodal computer-mediated Communication and social support among older chinese internet users. *Journal of computer-mediated communication 13(3)* , 728-749.

Yee, N. (2006). Motivations for playing online games. *Cyberpsychology & Behavior 9(6)* , 772-775.

Yee, N., Bailenson, J. N., Urbanek, M., Chang, F., & Merget, D. (2007). The Unbearable Likeness of Being Digital: The persistance of Nonverbal Social Norms in Online virutal environments. *Cyberpsychology & Behaviour 10(1)* , 115-119.

Zaphiris, P., & Sarwar, R. (2006). Trends, Similarities, and Differences in the Usage of Teen and Senior Public Online Newsgroups. *ACM Transactions on Computer-Human Interaction 13(3)* , 403-422.

Zhao, S. (2003). Towards a Taxonomy of Copresence. *Presence 12(5)* , 445-455.

Zhou, Z., Jin, X.-L., Vogel, D. R., Fang, Y., & Chen, X. (2011). Individual motivations and demographic differences in social virtual world uses: An exploratory investigation in Second Life. *International Journal of Information Management, 31(3)* , 261-271.

Zhou, Z., Jin, X.-L., Vogel, D., Xitong, G., & Chen, X. (2010). Individual Motivations for using Social Virtual worlds: An Exploratory Investigation in Second Life. *Proceedings of the 43rd Hawaii International Conference on System Sciences,5-8 Jan. 2010* , Hawaii, USA.

Zuckerman, M., & al, e. (1981). Verbal and nonverbal communication of deception. In L. Berkowitz, *ADV experimental social psychology 14* (pp. 2-60). New York: Academic Press.

Appendix

Appendix A: Details of the virtual worlds mentioned in this thesis

Footnote (in thesis)	Virtual world	Description	URL
1	World of Warcraft	A fantasy 3D MMORPG based on the Warcraft universe. Released in 2004 by Blizzard Entertainment. Similar to other MMORPGs, game play consists of fighting monsters to obtain rewards and items to strengthen the player's in-world character. Users could also join groups called "guilds" where they could socialize and carry out joint in-game activities with other players. Due to its popularity, this virtual world has been featured in a number of academic studies looking into MMORPGs (such as (Ducheneaut, Yee, & al, 2006)).	http://eu.battle.net/wow/en/
2	Everquest	A fantasy 3D MMORPG developed and published by Sony Entertainment. First version was released in 1999. Game play is similar to other MMORPGs (see World of Warcraft).	http://www.everquest.com/
3	Star wars galaxy	A 3D MMORPG based on the Star wars galaxy universe published by Lucas Arts. Released in 2003. Currently no longer in service.	http://www.swgalaxies.net/
4	Second Life	An extremely popular open-ended virtual world developed by Linden Labs. The main design philosophy of this virtual world was to encourage user-generated experience and content. Users can sell objects they create inside the virtual world for physical world money. Second Life is frequently featured in academic research and has received considerable attention by those looking to use virtual worlds for serious purposes such as Healthcare and Education.	http://secondlife.com/

5	IMVU	IMVU contains many of the features which are found in other open-ended virtual worlds (Sivan, 2008). Users can create their own in-world objects and are able to socialize with each other through a 3D platform. In addition, users can also join a number of groups with a wide range of topics. The virtual world also has a social network element which contains profile pages of users.	http://www.imvu.com/
6	Habitat	A 2D Multi-player online virtual environment developed by Lucasfilms in 1985. This virtual world was one of the first large scale online spaces where users were represented using graphical avatars. Users can manipulate objects in the game and communicate with other players using text base communication.	No longer in service, see: (Morningstar, Farmer, & Researchers, 2008)
7	Twinity	A 3D online social virtual world. The environments in this virtual world were created based on replicas of physical world locations. Therefore, this virtual world could also be considered as a Mirror world.	http://www.twinity.com
8	Empire of Sports	Described as a sport based MMOG. In this virtual world, users play as an athlete and can compete in a number of sports such as Football, Basketball and Skiing. Currently in beta testing (as of Oct 2012)	https://www.empireofsports.com/en/index.html
9	Active worlds	An open ended 3D virtual world. Active worlds host a number of "Universes", some focusing on a specific aspect such as the Active worlds educational universe which focuses on education. The company which developed this virtual world also offer platforms for users to host their own stand-alone virtual environment. Active worlds is the successor of Alpha world, one of the first virtual worlds to be represented using 3D graphics that generated a sizable community.	http://www.activeworlds.com/
10	There	A 3D social virtual world released in 2003 by There inc. Similar to other social virtual worlds, users could customize their avatars, create objects in the virtual world and sell them to other users. This virtual world also contains a commerce system where virtual world money could be exchanged for physical world money.	http://www.there.com/

15	Utherverse	A 3D virtual world. Users could access this world through a 3D plug-in installed on their web browser. This platform was designed to be "the next generation of the internet". One of the popular worlds is "the red Light Center", an adult themed virtual world.	http://www.utherverse.com/index.aspx
16	Omnidate	A dating site which uses a 3D virtual environment to allow members to go on "virtual dates" with each other. A number of interactions such as flirting, kissing and hugging are available. Members could also play games designed to provoke conversation with each other.	http://www.omnidate.com/

Appendix B: Interview Questions/ Interview Schedule used in the exploratory interview study in chapter 3

0. Introduction phase

0.1 Help establish rapport, Introduce myself first (self disclosure) and introduce the purpose of the study and the activity which would take place, ask participants to sign the online consent form

1. Demographics

- Please tell me a little bit about yourself.
-Would you say so are familiar with computers, IT and the internet? What do you usually use the internet for? (Social network, casual online games etc?)

2. Usage pattern, activities and interest in using virtual world

- Please tell me about how you got to use Second Life / IMVU?
- How often do you use Second Life / IMVU?
- What would you say are the reasons you're using Second Life / IMVU?
- What would you say is the main reason you're using Second Life / IMVU?
- Could you please tell me how your typical session in Second Life / IMVU goes? [Open-ended starter]
- Please describe the activities you usually do in second Life/ IMVU?
  -Are there any activities you find particularly entertaining?
- Do you create content? What type, Why not?
- How do you feel about inhabiting a virtual world as opposed to the one you live in real life?

3. Social engagement & Relationships

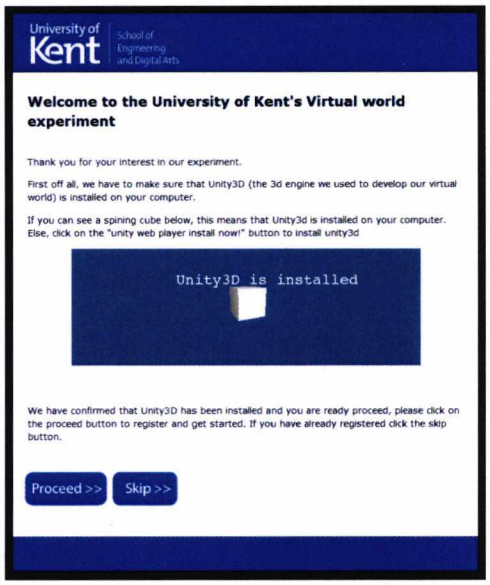
- How do you feel about your social experience in Second Life/ IMVU?
- Where you able to meet new people in Second Life/IMVU?
  - How do you get to meet new people? / Do you join any activities or groups?
- Do you have a group of people you know very well in Second Life/ IMVU?
  - Do you consider them close friends? / What activities do you do together?
- How do you think Second Life compares to other forms of electronic communication technologies that you have used?

4. Benefit

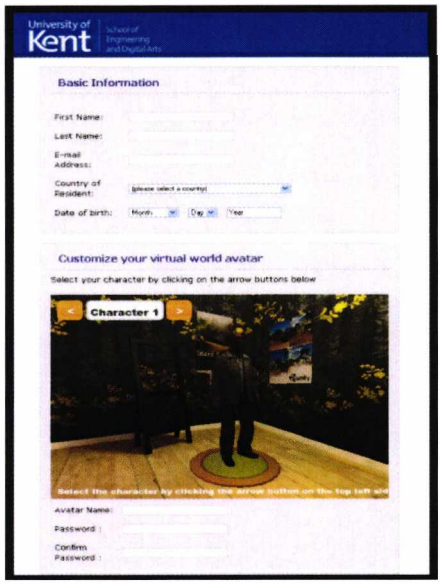
- Do you think using Second Life/ IMVU has any benefits to you personally?
  -When you grow older? Provides a benefit unobtainable in Real life? Keeps you mentally active/ socially connected?

5. Thanking the participants for allowing us to conduct the interview

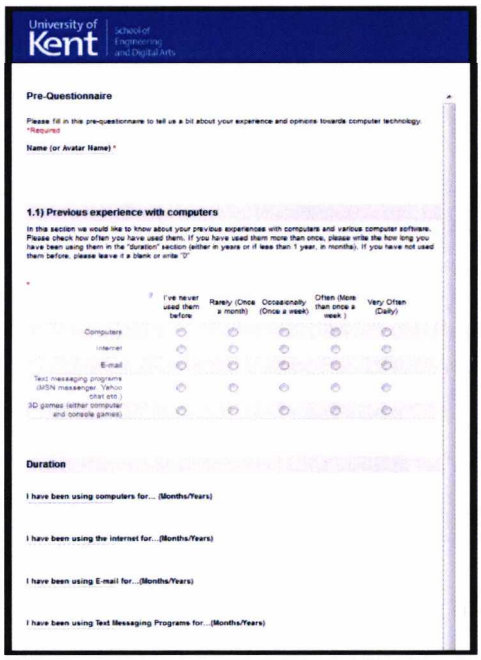
Appendix C: Screenshots of the virtual world system used in the virtual island study



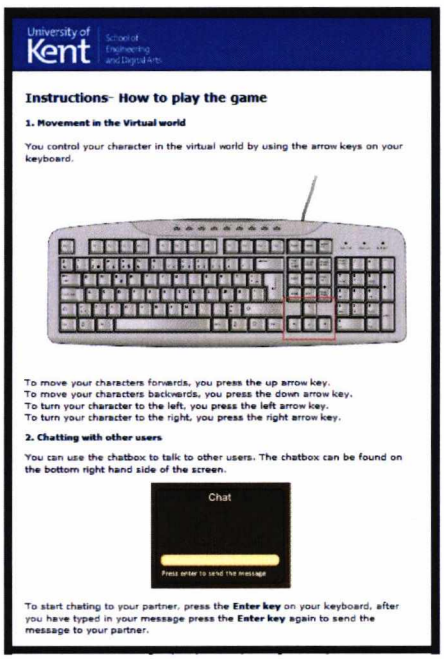
1) Welcome page



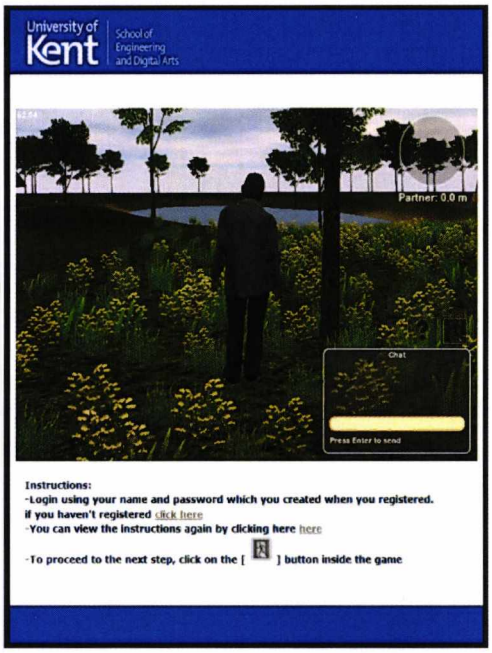
2) Registration and Avatar selection



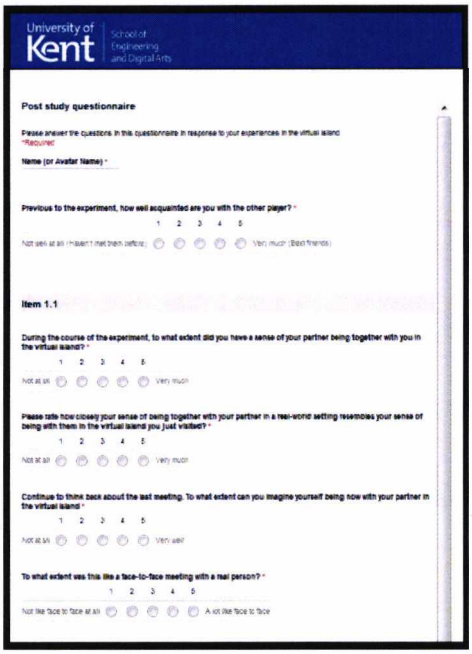
3)Pre-Questionaire



4) Instructions

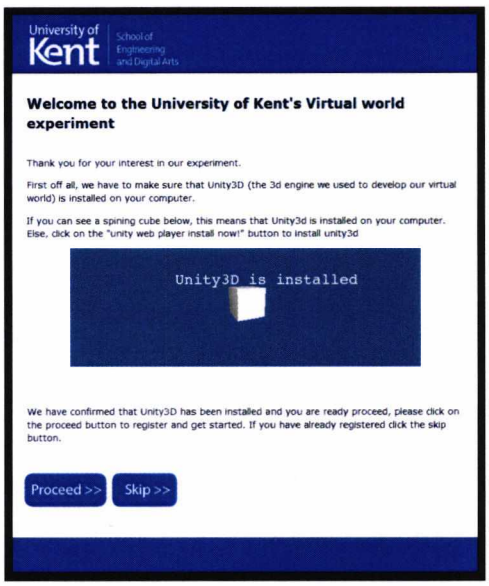


5) Virtual island

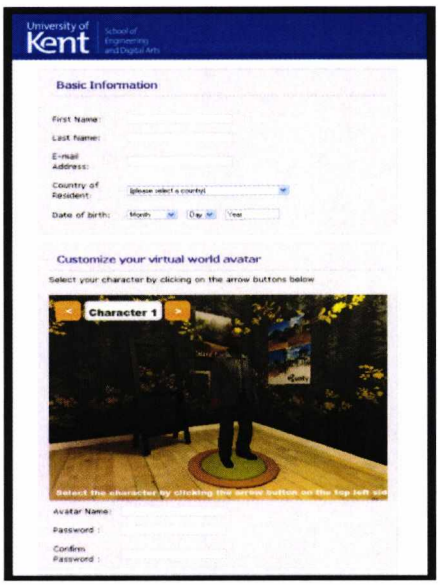


6) Post questionnaire

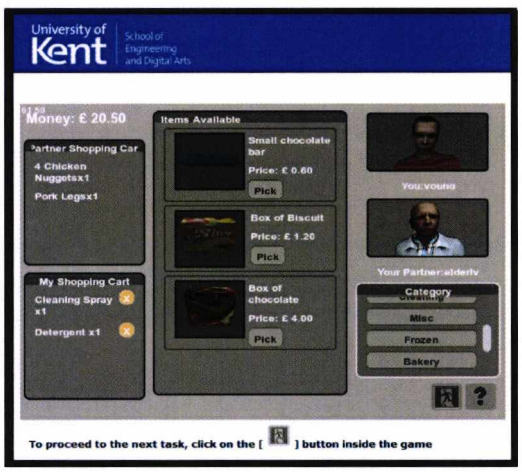
Appendix D: Screenshots of the virtual world system used in the virtual store study



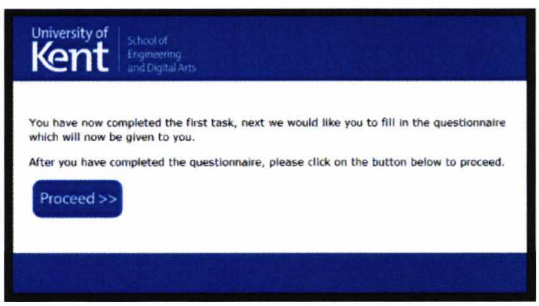
1) Welcome page



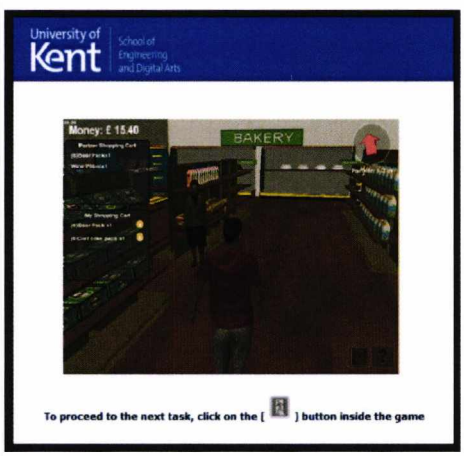
2) Registration and Avatar selection



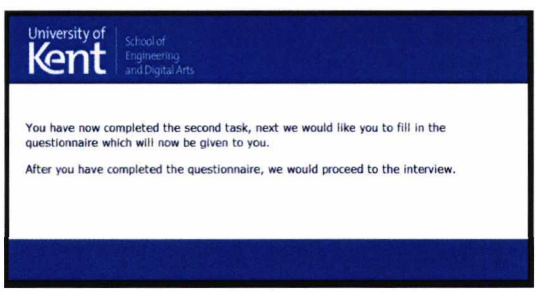
3) 2D virtual store



4) Post Questionnaire 1



5) 3D virtual store



6) Post Questionnaire 2

Appendix E: Virtual island study questionnaires

Pre-Questionnaire

Part 1. General information

Name _____

Age _____ Gender _____

1.1) Previous experience with computers

In this section we would like to know about your previous experiences with computers and various computer software. Please place a cross in the table below to indicate how often you have used them. If you have used them more than once, please write the how long you have been using them in the "duration" section (either in years or if less than 1 year, in months)

	I've never used them before	Rarely (Once a month)	Occasionally (Once a week)	Often (more than once a week)	Very Often (Daily)	**Duration**
Computers						
Internet						
E-mail						
Text Messaging programs (MSN messenger, Yahoo chat etc)						
3D games (either computer and console games)						

1.2) About your health

Please place a circle around a number to indicate which of the opposite opinions you agree with most. Rate this on a scale of 1 to 5 where 1 indicates that you agree most with the opinion on the left and 5 indicates that you agree most with the opinion on the right.

1. To what extent does your physical condition require you to exert more effort to perform daily activities?						
Not at all	1	2	3	4	5	Very much

2. To what extent does your physical condition limit the kind of activities you can perform?						
Not at all	1	2	3	4	5	Very much

3. To what extent does your physical condition cause you difficulty in performing daily activities?						
Not at all	1	2	3	4	5	Very much

1.3) About your opinions towards Computers and Technology

Please note that computer mediated communication refers to any kind of communication to another person taking place via a computer (such as e-mail, chat rooms or web forums for instance)

1. To what extent do you feel that "Using and manipulating a computer and its auxiliary devices (such as printers, scanners or Floppy discs etc) make me feel uneasy"						
Not at all	1	2	3	4	5	Very much

2. To what extent do you feel that "it is impossible to express feelings adequately in computer mediated communication "						
Not at all	1	2	3	4	5	Very much

3. To what extent do you feel that "Computers and its auxiliary devices (such as printers, scanners or Floppy discs etc) make me nervous"						
Not at all	1	2	3	4	5	Very much

4. To what extent do you feel that "getting to know someone using computer mediated communication is impossible"						
Not at all	1	2	3	4	5	Very much

5. To what extent do you agree with the statement "I get worried when I think of using a computer and its auxiliary devices (such as printers, scanners or Floppy discs etc)"						
Not at all	1	2	3	4	5	Very much

6. To what extent do you agree with the statement "getting to know each other via computer mediated communication is possible only under the condition that people are willing to show their true attitudes and emotions"						
Not at all	1	2	3	4	5	Strongly Agree

1.4) level of acquaintance

Please rate how well you know your partner before the experiment on a scale of 1 to 5, where 5 indicates that you knew your partner very well and 1 indicates that you have never met your partner before.

1. Previous to this experiment, how well would you say you knew your partner?						
Not well at all	1	2	3	4	5	Very well

Post Questionnaire

In this questionnaire, please place a circle around a number to indicate which of the opposite opinions you agree with most. Rate this on a scale of 1 to 5 where 1 indicates that you agree most with the opinion on the left and 5 indicates that you agree most with the opinion on the right.

Please note that "virtual island" refers to the 3D island you just visited with your partner.

Item 1.1

1. During the course of the experiment, to what extent did you have a sense of your partner being together with you in the virtual island?						
Not at all	1	2	3	4	5	Very much

2. Please rate how closely your sense of being together with other people in a real-world setting resembles your sense of being with them in the virtual island you just visited?						
Not at all	1	2	3	4	5	Very much

3. Continue to think back to the last meeting, to what extent can you imagine yourself being now with your partner in the virtual island?						
Not at all	1	2	3	4	5	Very much

4. To what extent was this like a face-to-face conversation with a real person?						
Not like face to face at all	1	2	3	4	5	A lot like face to face

5. To what extent did you feel you could get to know someone that you just met through this system?						
Not at all	1	2	3	4	5	very well

6. To what extend did you feel able to assess your partner's reactions to what you said?						
not able to assess reactions	1	2	3	4	5	Able to assess reactions

Item 1.2

Please evaluate the quality of the communication with your partner based on the ability of the platform (computer program) you just used.

1. How well do you feel you were able to understand what your partner was saying?						
Not at all	1	2	3	4	5	Very well

2. How well do you feel you were able to express yourself with your partner?						
Not at all	1	2	3	4	5	Very well

3. How well do you think your partner understood what you meant to communicate?						
Not at all	1	2	3	4	5	Very well

4. How much control did you have over the conversation?						
No control	1	2	3	4	5	Total control

Item 1.3

1. How well do you think you and your partner performed on the task you were given?						
Not at all well	1	2	3	4	5	Very well

2. How satisfied are you with the outcome to the task?						
Very unsatisfied	1	2	3	4	5	Very satisfied

3. How strong do you think you and your partner's agreement is to the final outcome?						
Not at all	1	2	3	4	5	Very strong

Item 1.4

1. To what extent did you enjoy using the virtual island?						
Not at all	1	2	3	4	5	Very much

2. Was your social experience in the virtual island satisfactory?						
Very unsatisfactory	1	2	3	4	5	Very satisfactory

Item 2.1

The 3D models which you control and choose to represent yourself in the 3D island are referred to as *avatars*

1. How useful to the interaction do you think the avatars were?						
Not at all	1	2	3	4	5	very

2. Were you paying attention to other people's avatars during the task?						
Not at all	1	2	3	4	5	All the time

3. How natural did the avatars seem?						
not at all natural	1	2	3	4	5	very natural

Item 2.2

1. When you think back to the experience, do you think of the virtual island more as...						
images that you saw	1	2	3	4	5	somewhere you visited

2. To what extent were there times during your experience that the virtual island became real or present for you compared to the real world?						
At no time	1	2	3	4	5	Almost all the time

3. To what extent did you have a sense of "being there" in the virtual island?						
Not at all	1	2	3	4	5	All the time

Item 2.3

1. How easy was it to explore what products were available in the virtual island?						
very difficult	1	2	3	4	5	Very easy

2. How easy was it to find something in the island?						
very difficult	1	2	3	4	5	Very easy

3. How easy was it to inspect or gather details about a particular object in the island?						
very difficult	1	2	3	4	5	Very easy

Appendix F: Virtual store study questionnaires

Pre-Questionnaire

Part 1. General information

Name _____

Age _____ Gender _____

1.1) Previous experience with computers

In this section we would like to know about your previous experiences with computers and various computer software. Please place a cross in the table below to indicate how often you have used them. If you have used them more than once, please write the how long you have been using them in the "duration" section (either in years or if less than 1 year, in months)

	I've never used them before	Rarely (Once a month)	Occasionally (Once a week)	Often (more than once a week)	Very Often (Daily)	**Duration**
Computers						
Internet						
E-mail						
Voice communication software (skype, etc)						
3D games (either computer and console games)						

1.2) About your health

Please place a circle around a number to indicate which of the opposite opinions you agree with most. Rate this on a scale of 1 to 5 where 1 indicates that you agree most with the opinion on the left and 5 indicates that you agree most with the opinion on the right.

1. To what extent does your physical condition require you to exert more effort to perform daily activities?						
Not at all	1	2	3	4	5	Very much

2. To what extent does your physical condition limit the kind of activities you can perform?						
Not at all	1	2	3	4	5	Very much

3. To what extent does your physical condition cause you difficulty in performing daily activities?						
Not at all	1	2	3	4	5	Very much

1.3) About your opinions towards Computers and Technology

Please note that computer mediated communication refers to any kind of communication to another person taking place via a computer (such as e-mail, chat rooms or web forums for instance)

1. To what extent do you feel that "Using and manipulating a computer and its auxiliary devices (such as printers, scanners or Floppy discs etc) make me feel uneasy"						
Not at all	1	2	3	4	5	Very much

2. To what extent do you feel that "it is impossible to express feelings adequately in computer mediated communication "						
Not at all	1	2	3	4	5	Very much

3. To what extent do you feel that "Computers and its auxiliary devices (such as printers, scanners or Floppy discs etc) make me nervous"						
Not at all	1	2	3	4	5	Very much

4. To what extent do you feel that "getting to know someone using computer mediated communication is impossible"						
Not at all	1	2	3	4	5	Very much

5. To what extent do you agree with the statement "I get worried when I think of using a computer and its auxiliary devices (such as printers, scanners or Floppy discs etc)"						
Not at all	1	2	3	4	5	Very much

6. To what extent do you agree with the statement "getting to know each other via computer mediated communication is possible only under the condition that people are willing to show their true attitudes and emotions"						
Not at all	1	2	3	4	5	Strongly Agree

1.4) level of acquaintance

Please rate how well you know your partner before the experiment on a scale of 1 to 5, where 5 indicates that you knew your partner very well and 1 indicates that you have never met your partner before.

1. Previous to this experiment, how well would you say you knew your partner?						
Not well at all	1	2	3	4	5	Very well

Post Questionnaire: 2D Task

In this questionnaire, please place a circle around a number to indicate which of the opposite opinions you agree with most. Rate this on a scale of 1 to 5 where 1 indicates that you agree most with the opinion on the left and 5 indicates that you agree most with the opinion on the right.

Please note that "virtual store" refers to the non 3D virtual store you just visited with your partner.

Item 1.1

1. During the course of the experiment, to what extent did you have a sense of your partner being together with you in the virtual store?						
Not at all	1	2	3	4	5	Very much

2. Please rate how closely your sense of being together with other people in a real-world setting resembles your sense of being with them in the virtual store you just visited?						
Not at all	1	2	3	4	5	Very much

3. To what extent was this like a face-to-face conversation with a real person?						
Not like face to face at all	1	2	3	4	5	A lot like face to face

4. To what extent did you feel you could get to know someone that you just met through this system?						
Not at all	1	2	3	4	5	very well

5. To what extend did you feel able to assess your partner's reactions to what you said?						
not able to assess reactions	1	2	3	4	5	Able to assess reactions

Item 1.2

Please evaluate the quality of the communication with your partner based on the ability of the platform (computer program) you just used.

1. How well do you feel you were able to understand what your partner was saying?						
Not at all	1	2	3	4	5	Very well

2. How well do you feel you were able to express yourself with your partner?						
Not at all	1	2	3	4	5	Very well

3. How well do you think your partner understood what you meant to communicate?						
Not at all	1	2	3	4	5	Very well

4. How much control did you have over the conversation?						
No control	1	2	3	4	5	Total control

Item 1.3

1. How well do you think you and your partner performed on the task you were given?						
Not at all well	1	2	3	4	5	Very well

2. How satisfied are you with the outcome to the task?						
Very unsatisfied	1	2	3	4	5	Very satisfied

3. How strong do you think you and your partner's agreement is to the final outcome?						
Not at all	1	2	3	4	5	Very strong

Item 1.4

1. To what extent did you enjoy using the virtual store?						
Not at all	1	2	3	4	5	Very much

2. Was your social experience in the virtual store satisfactory?						
Very unsatisfactory	1	2	3	4	5	Very satisfactory

Item 2.1

The "avatar" refers to the 2D image which represented you and your partner in the virtual world

1. How useful to the activity do you think the avatars were?						
Not at all	1	2	3	4	5	very

2. Were you paying attention to other people's avatars during the task?						
Not at all	1	2	3	4	5	All the time

3. How natural did the avatars seem?						
not at all natural	1	2	3	4	5	very natural

Item 2.2

1. When you think back to the experience, do you think of the virtual store more as...						
images that you saw	1	2	3	4	5	somewhere you visited

2. To what extent did you have a sense of "being there" in the virtual store?						
Not at all	1	2	3	4	5	All the time

3. To what extent were there times during your experience that the virtual store became real or present for you compared to the real world?						
At no time	1	2	3	4	5	Almost all the time

Item 2.3

1. How easy was it to explore what products were available in the store?						
very difficult	1	2	3	4	5	Very easy

2. How easy was it to find a particular product in the store?						
very difficult	1	2	3	4	5	Very easy

3. How easy was it to inspect or gather details about a particular product in the store?						
very difficult	1	2	3	4	5	Very easy

Post Questionnaire: 3D Task

In this questionnaire, please place a circle around a number to indicate which of the opposite opinions you agree with most. Rate this on a scale of 1 to 5 where 1 indicates that you agree most with the opinion on the left and 5 indicates that you agree most with the opinion on the right.

Please note that "virtual store" refers to the 3D store you just visited with your partner.

Item 1.1

1. During the course of the experiment, to what extent did you have a sense of your partner being together with you in the virtual store?						
Not at all	1	2	3	4	5	Very much

2. Please rate how closely your sense of being together with other people in a real-world setting resembles your sense of being with them in the virtual store you just visited?						
Not at all	1	2	3	4	5	Very much

3. To what extent was this like a face-to-face conversation with a real person?						
Not like face to face at all	1	2	3	4	5	A lot like face to face

4. To what extent did you feel you could get to know someone that you just met through this system?						
Not at all	1	2	3	4	5	very well

5. To what extend did you feel able to assess your partner's reactions to what you said?						
not able to assess reactions	1	2	3	4	5	Able to assess reactions

Item 1.2

Please evaluate the quality of the communication with your partner based on the ability of the platform (computer program) you just used.

1. How well do you feel you were able to understand what your partner was saying?						
Not at all	1	2	3	4	5	Very well

2. How well do you feel you were able to express yourself with your partner?						
Not at all	1	2	3	4	5	Very well

3. How well do you think your partner understood what you meant to communicate?						
Not at all	1	2	3	4	5	Very well

4. How much control did you have over the conversation?						
No control	1	2	3	4	5	Total control

Item 1.3

1. How well do you think you and your partner performed on the task you were given?						
Not at all well	1	2	3	4	5	Very well

2. How satisfied are you with the outcome to the task?						
Very unsatisfied	1	2	3	4	5	Very satisfied

3. How strong do you think you and your partner's agreement is to the final outcome?						
Not at all	1	2	3	4	5	Very strong

Item 1.4

1. To what extent did you enjoy using the virtual store?						
Not at all	1	2	3	4	5	Very much

2. Was your social experience in the virtual store satisfactory?						
Very unsatisfactory	1	2	3	4	5	Very satisfactory

Item 2.1

The 3D models which you control and choose to represent yourself in the 3D store and 3D environment are referred to as *avatars*

1. How useful to the interaction do you think the avatars were?						
Not at all	1	2	3	4	5	very

2. Were you paying attention to other people's avatars during the task?						
Not at all	1	2	3	4	5	All the time

3. How natural did the avatars seem?						
not at all natural	1	2	3	4	5	very natural

Item 2.2

1. When you think back to the experience, do you think of the virtual store more as...						
images that you saw	1	2	3	4	5	somewhere you visited

2. To what extent did you have a sense of "being there" in the virtual store?						
Not at all	1	2	3	4	5	All the time

3. To what extent were there times during your experience that the virtual store became real or present for you compared to the real world?						
At no time	1	2	3	4	5	Almost all the time

Item 2.3

1. How easy was it to explore what products were available in the store?						
very difficult	1	2	3	4	5	Very easy

2. How easy was it to find a particular product in the store?						
very difficult	1	2	3	4	5	Very easy

3. How easy was it to inspect or gather details about a particular product in the store?						
very difficult	1	2	3	4	5	Very easy

Appendix G: Coefficients of the multiple regression models used in the virtual store study

Models constructed using the platform factors (physical presence, navigation and avatar) for the 3D store

Social presence

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.715	0.333		5.152	0
Presence	0.561	0.101	0.681	5.576	0

a. Dependent Variable: Social Presence

Excluded Variables[b]

Model	Beta In	t	Sig.
Navigation	.143[a]	0.866	0.392
Avatar	-.053[a]	-0.299	0.767

a. Predictors in the Model: (Constant), Presence

b. Dependent Variable: Social Presence

Quality of communication

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.324	0.342		9.73	0
Presence	0.26	0.103	0.387	2.521	0.016

a. Dependent Variable: Quality of communication

Excluded Variables[b]

Model	Beta In	t	Sig.
Navigation	.162[a]	0.779	0.441
Avatar	-.162[a]	-0.722	0.475

a. Predictors in the Model: (Constant), Presence

b. Dependent Variable: Quality of communication

Performance

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.034	0.374		8.11	0
Navigation	0.391	0.116	0.491	3.381	0.002

a. Dependent Variable: Performance

Excluded Variables[b]

Model	Beta In	t	Sig.
Presence	.214[a]	1.097	0.28
Avatar	-.133[a]	-0.658	0.515

a. Predictors in the Model: (Constant), Navigation

b. Dependent Variable: Performance

Overall satisfaction in social experience

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	0.258	0.424		0.61	0.546
Presence	0.676	0.155	0.592	4.364	0
Navigation	0.339	0.167	0.276	2.032	0.05

a. Dependent Variable: Satisfaction

Excluded Variables[c]

Model	Beta In	t	Sig.
Avatar	.071[b]	0.439	0.663

a. Predictors in the Model: (Constant), Presence

b. Predictors in the Model: (Constant), Presence, Navigation

c. Dependent Variable: Overall Satisfaction

Enjoyment

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.571	0.469		3.353	0.002
Presence	0.401	0.171	0.394	2.341	0.025
Navigation	0.376	0.185	0.343	2.039	0.049

a. Dependent Variable: Enjoyment

Model	Beta In	t	Sig.
Avatar	.255[b]	1.308	0.2

a. Predictors in the Model: (Constant), Presence

b. Predictors in the Model: (Constant), Presence, Navigation

c. Dependent Variable: Enjoyment

Models constructed using the computer experience factors (E-mail, Skype, 3D games) for the 3D store

Social presence

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.864	.331		8.656	.000
Games	.245	.115	.339	2.131	.040

a. Dependent Variable: Social presence

Excluded Variables

Model	Beta In	t	Sig.
Email	-.268[a]	-1.729	.093
skype	-.096[a]	-.508	.615

a. Predictors in the Model: (Constant), Games

b. Dependent Variable: Social presence

For *quality of communication, Performance, Overall Satisfaction in social experience and enjoyment* all the tested variables were excluded and thus no significant model was constructed.

Models constructed using the user characteristics factor (computer anxiety, level of acquaintance and health) for the 3D store

For *Social presence, quality of communication, Performance, Overall Satisfaction in social experience and enjoyment* all the tested variables were excluded and thus no significant model was constructed.

Models constructed using the platform factors (physical presence, navigation and avatar) for the non 3D store

Social presence

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	2.54	0.308		8.252	0
Presence	0.394	0.11	0.513	3.582	0.001

a. Dependent Variable: social presence

Excluded Variables[b]

Model	Beta In	t	Sig.
Navigation	.217[a]	1.529	0.135
Avatar	-.125[a]	-0.658	0.515

a. Predictors in the Model: (Constant), Presence

b. Dependent Variable: Social presence

Quality of communication

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3.005	0.443		6.78	0
Navigation	0.309	0.106	0.437	2.914	0.006

a. Dependent Variable: Quality of communication

Excluded Variables[b]

Model	Beta In	t	Sig.
Presence	.274[a]	1.868	0.07
Avatar	.137[a]	0.898	0.375

a. Predictors in the Model: (Constant), Navigation

b. Dependent Variable: Quality of communication

Performance

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3.408	0.427		7.973	0
Navigation	0.252	0.102	0.38	2.461	0.019

a. Dependent Variable: Performance

Excluded Variables[b]

Model	Beta In	t	Sig.
Presence	.215[a]	1.398	0.171
Avatar	.107[a]	0.679	0.501

a. Predictors in the Model: (Constant), Navigation

b. Dependent Variable: Performance

Overall satisfaction in social experience

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-0.189	0.779		-0.243	0.809
Presence	0.509	0.126	0.5	4.048	0
Navigation	0.602	0.182	0.408	3.302	0.002

a. Dependent Variable: Overall Satisfaction

Excluded Variables[c]

Model	Beta In	t	Sig.
Avatar	.013[b]	0.079	0.938

a. Predictors in the Model: (Constant), Presence

b. Predictors in the Model: (Constant), Presence, Navigation

c. Dependent Variable: Overall Satisfaction

Enjoyment

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.043	0.353		8.628	0
Presence	0.401	0.126	0.469	3.185	0.003

a. Dependent Variable: Enjoyment

Excluded Variables[b]

Model	Beta In	t	Sig.
Navigation	.275[a]	1.91	0.064
Avatar	.142[a]	0.724	0.474

a. Predictors in the Model: (Constant), Presence

b. Dependent Variable: Enjoyment

Models constructed using the computer experience factors (E-mail, Skype, 3D games) for the non 3D store

For *quality of communication, Performance, Overall Satisfaction in social experience and enjoyment* all the tested variables were excluded and thus no significant model was constructed.

Models constructed using the user characteristics factor (computer anxiety, level of acquaintance and health) for the non 3D store

For *quality of communication, Performance, Overall Satisfaction in social experience and enjoyment* all the tested variables were excluded and thus no significant model was constructed.