Age-related cognitive decline and navigation in electronic environments

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ABSTRACT

The older population is increasing, as is life expectancy. Technical devices are becoming more widespread and used for many everyday tasks. Knowledge about new technology is important to remain as an active and independent part of the society. However, if an old user group should have equal access to this technology, new demands will be placed on the design of interfaces and devices. With respect to old users it is and will be important to develop technical devices and interfaces that take the age-related decline in physical and cognitive abilities into account. The aim of this work was to investigate to what extent the age-related cognitive decline affects performance on different computer-related tasks and the use of different interfaces. With respect to the use of computer interfaces, two studies were conducted. In the first study, the information was presented with a hierarchical structure. In the second study the information was presented as a 3D-environment, and it was also investigated how an overview map could support navigation. The third study examined the age-related cognitive decline in the use of a small mobile phone display with a hierarchical information structure. The results from the studies showed that the most pronounced age-related difference was found in the use of the 3D-environment. Within this environment, prior experience was found to have the largest impact on performance. Regarding the hierarchical information structures, prior experience seemed to have a larger impact on performance of easy tasks, while age and cognitive abilities had a larger impact on performance of more complex tasks. With respect to navigation aids, the overview map in the 3D-environment did not reduce the age-differences; however, it contributed to a better perceived orientation and reduced the feeling of being lost.

Keywords: Ageing, cognition, navigation, computers, Internet, mobile phones, interface design

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Finally I would like to thank family and friends for support during the years that I have been working with this thesis.

A really big hug to Oscar, Stina, Frida and Gustav!

"I am not young enough to know everything." ~ Oscar Wilde

LIST OF STUDIES

The presented thesis is based on the following studies:

Study 1: Sjölinder, M, Höök, K, & Nilsson, L.-G. (2003) The effect of age-related cognitive differences, task complexity and prior Internet experience in the use of an online grocery shop. *Spatial Cognition and Computation, 3*, 61-84.

Study 2: Sjölinder, M, Höök, 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.

Study 3: Sjölinder, M., Nilsson, L.-G., Bergqvist, M. & Höök, K. (2006). Age-related cognitive decline and the use of mobile phones and mobile services. Submitted to Behaviour and Information Technology.

CONTRIBUTIONS TO THE CONDUCTED WORK

Sjölinder designed (supervised by Nilsson) the studies, partially conducted the studies, performed the statistical analyses, and wrote the articles (supervised by Nilsson & Höök).

Nilsson supervised the design of the studies, the use of statistical analyses, and the work in general. Höök contributed with input regarding design implications and served as a partner for discussions.

Andersson conducted the second study in cooperation with Sjölinder, and Bergqvist conducted the third study in cooperation with Sjölinder.

Study 1

Authors: Sjölinder, Höök and Nilsson

Sjölinder designed (supervised by Nilsson) the study, conducted the study, performed the statistical analyses (supervised by Nilsson), and wrote the article (supervised by Nilsson & Höök).

Study 2

Authors: Sjölinder, Höök, Nilsson and Andersson

Sjölinder designed (supervised by Nilsson) the study, performed the statistical analyses (supervised by Nilsson), and wrote the article (supervised by Nilsson & Höök).

Study 3

Authors: Sjölinder, Nilsson, Bergqvist and Höök

Sjölinder designed (supervised by Nilsson) the study, performed the statistical analyses (supervised by Nilsson), and wrote the article (supervised by Nilsson & Höök).

Background and context

The work for this thesis is based on previous conducted work (and publications) together with Nils Dahlbäck and Kristina Höök, on individual differences in the navigating interfaces (Dahlbäck, Höök & Sjölinder, 1996). Other own work related to older users is a study that investigated older adults and effect related to the use of computer games. This study was conducted together with Carolin Molander and Annika Waern. Projects on affective computing and user experiences (Höök, Persson & Sjölinder, 2003; Höök, Persson & Sjölinder, 2000), projects on mobile services and user needs (Andersson et al., 2004; Bylund, Sjölinder & Danestig, 2004a; Bylund, Sjölinder & Eriksson, 2004b), and work regarding the use of different methods to capture user needs have also inspired and influenced the work conducted for this thesis.

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1. INTRODUCTION

The population in the world is growing older (Morrell, Mayhorn & Bennett, 2002) and the research efforts related to healthy ageing are increasing within many areas (Wetle, 2002). The reliance on technical devices is also rapidly increasing (Morrell et al., 2002), and the use of computers and the Internet is becoming more widespread and used for many everyday tasks. Older adults can benefit in several ways from using computers and the Internet and this group of Internet users is the fastest growing user group (Hanson et al., 2001; Morrell, 2001; Morrell et al., 2002). The use of computers and the Internet among older adults can contribute to improve quality of life (Mead, Batsakes, Fisk & Mykityshyn, 1999), in terms of possibilities to communicate with others or receive information regardless of geographical location or physical limitations (McConatha, 2002). The possibilities for social interaction also increase as a result of access to the Internet, e-mail and discussion forums (Czaja, 1996; Morris, 1994). The possibilities for older adults to remain as an active part of the society increases when new ways are provided for exchanging information or receive information about different topics (McConatha, 2002). When computers and the Internet become available for older of the population, their control over important information increases. As a result, older adults' status within society increases (McConatha, 2002). Several studies have showed that people who have learned how to use computers and the Internet have gained higher self-esteem and increased their social interaction (Cody, Dunn, Hoppin & Wendt, 1999; Hendrix, 2000).

During the past 10 years, research on ageing and the use of computers (as well as other technical devices) has increased. Technical innovations directed towards older adults, or research regarding older adults and the use of technology can be conducted from several different perspectives and with several different aims. For example, technical innovations can be designed with the aim to compensate for or prevent age-related decline, or to assist in different situations (Östlund, 1999). Another aim or perspective is focusing on making devices and interfaces easy to use for everyone – including older adults. Within this approach, design is discussed in terms of "design for all" (Stephanidis, 1995; Stephanidis & Savidis, 2001; Östlund, 1999), or "design for diversity" where all user-groups' presuppositions are taken into account (Shneiderman, 2001). Standardization work has been conducted regarding usability of everyday products, including interfaces. The standard developed (ISO, 2001) specify information about product usability, which should be provided with a consumer product. The aim is to make it possible for the customer to judge the ease of use of the product, based on, for example, the characteristics of users with special needs, their skills, or previous experience (Bevan & Schoeffel, 2001).

If computers and the Internet are going to be used by a majority of the older adults, both today and in the future, technical devices and interfaces must be easy to use despite of changes due to age in physical and cognitive functions. Design considerations related to these issues will of course be an advantage for everyone regardless of age. For the older part of the population, it might be especially important since the technology also contributes to maintaining status and remaining as an active part of the society.

However, many interfaces are currently not easy to use for everyone, neither do they take older users presuppositions into account. In studies of older computer users, it has been found that older adults usually face larger difficulties than younger adults in learning and using new computer applications (Kelly & Charness, 1995), that their learning process is longer (Kelly & Charness, 1995) and that they need more time to solve different tasks (Kubeck, Miller-Albrecht & Murphy, 1999; Mead, Sit, Rogers, Jamieson & Rousseau, 2000; Sjölinder, Höök & Nilsson, 2003). Further, it is more difficult for older adults to handle large information spaces, to sort out task-relevant information, and to deal with complex information (Kubeck et al., 1999; Morris & Venkatesh, 2000). Some of the age-related differences related to performance with computers can be explained by the age-related cognitive decline (Czaja, 1996; Czaja & Sharit, 1997; Kelly & Charness, 1995), since many cognitive functions decline with age (Czaja, 1996; Light & Zelinski, 1983; Nilsson et. al., 1997; Salthouse, 1982). If an older user group should have equal access to this technology, new demands will be placed on the design of interfaces and devices. If computers and other technical devices are going to be a channel for information and communication for everyone, the age-related differences and the decline in cognitive abilities must be taken into account when providing new technology intended for all. The age-related decline in different cognitive functions must be investigated with respect to how it affects the use of different interfaces and performance of different tasks. There is a need to understand which age-sensitive cognitive functions play the largest role in different situations when conducting computer-related tasks, as well as how to compensate for this age-related cognitive decline when designing interfaces.

The aim with this thesis has been to investigate age-related cognitive changes in the use of different interfaces (computer interface and mobile phone interface), different information structures (hierarchical and three dimensional), and different tasks (different levels of complexity). The work in this thesis has been conducted within the approach of designing interfaces that are easy to use (for as many people as possible) – with a particular focus on older adults.

Needless to say, older people are different from one another in all sorts of aspects. However, some important characteristics are more frequent in groups of older adults than in groups of younger adults. Several different approaches or attempts to divide older adults into subgroups have been made. According to Gregor, Newell & Zajicek (2002) one way is to distinguish between: *Fit older people* (older adults that not appear to be disabled, nor consider themselves disabled); *frail older people* (older adults with one or more disabilities and with a general reduction in many functionalities); and *disabled people who grow older* (older adults with disabilities that have affected the ageing process). The older group, which is discussed within this thesis or that have participated in the studies, mainly belong to the group of "fit older people".

Chapter 2 and 3 of this thesis consists of a quite extensive and broad introduction on different aspects related to older adults and the use of technology. Some of the discussed issues are not directly related to the conducted empirical work. However, the discussed aspects do affect older adults presupposition and possibilities to use computers and other devices. Therefore, they place the conducted work in a context, as well as providing a broader perspective on older adults and the use of computers and new technology. The experimental work described is followed by conclusions based upon the conducted work and previous research regarding age-related cognitive decline and the use of different interfaces and information structures. In chapter 5 of this thesis, design implications are discussed in terms of how to design interfaces that take the age-related decline into consideration.

2. OLDER ADULTS AND INFORMATION TECHNOLOGY

The number of older adults has increased during the last century and is also expected to continue to rise (Kinsella & Velkoff, 2001, Wetle, 2002). Sweden is one of the countries in the world that has the oldest population today (Kinsella & Velkoff, 2001). Between 1950 and 2003, the Swedish population over 65 increased from 10 % in 1950 (SCB, 1999) to 17 % in 2003 (SCB, 2004a). In most of the developed countries in Europe in 2000, the population over 65 years of age exceeds 12%. In some countries it even reaches up to 17-18 % (Kinsella & Velkoff, 2001) and in the United States, 12.3 % of the population was over 65 years of age in 2002 (U.S. Census bureau, 2003).

The population is also growing older (Morrell et al., 2002, Kinsella & Velkoff, 2001) with life expectancy rising in most of the Western Europe countries (Kinsella & Velkoff, 2001). Sweden is one of the countries with the highest life expectancy. Between 1980 and 2003, life expectancy increased from 72.8 years to 77.9 years for men, and from 78.8 years to 82.4 years for women (SCB, 2004a). However, life expectancy is high in most of the other countries in Western Europe as well. In 2000, it ranged between 76 and 79 years of age in most of the other countries in Western Europe (Kinsella & Velkoff, 2001). In the United States life expectancy also has risen. Between 1980 and 2000, it increased from 70.0 years to 74.1 years for men and from 77.4 years to 79.5 years for women (Minino, Arias, Kochanek, Murphy & Smith, 2002).

In the future, it can be expected that more than 12% - 18% of the population in the Western world will be older than 65 years and they are likely to live to around 75-80 years of age. Addressing the needs of this growing population in terms of IT-based devices and services will not only be necessary for societal and health reasons, but also important from a market perspective.

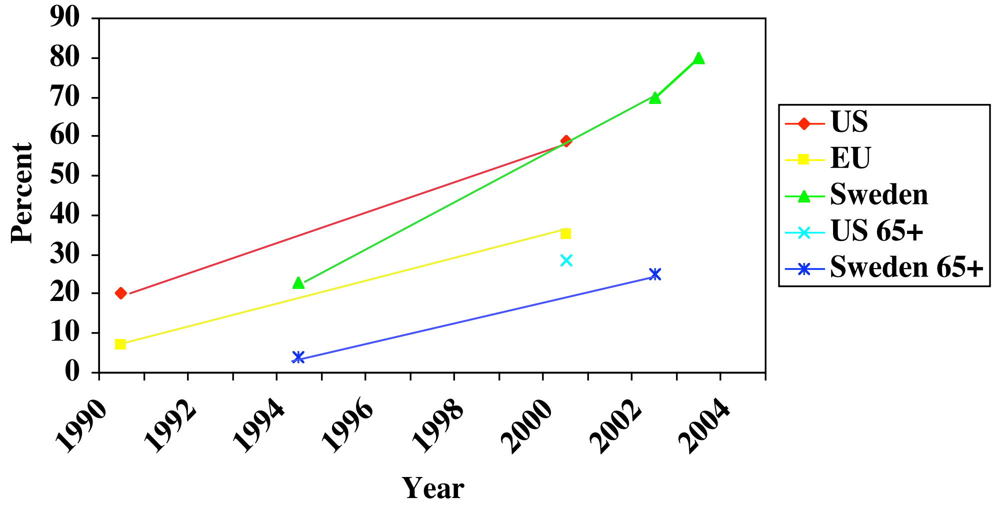
2.1. Access to and use of Information Technology among older adults

Reliance on different technical devices is spreading within the society, and many everyday tasks can be conducted with the use of computers and the Internet. Access to and use of computers, the Internet, and mobile phones has become a part of our daily lives, and many people take this technology for granted.

2.1.1. Access to and use of computers

There is an increasing access to and use of computers. In figure 1, the access to computers within the United States, the European Union (EU), and Sweden are shown. Within the United States population of those over 15 years of age, the number of PCs per 100 inhabitants had risen from 20 in 1990 to 59 in 2000 (Deiss, 2002), see table 1. Within the EU population of those over 15 years of age, the number of PCs per 100 inhabitants had increased from 7 in 1990 to 35 in 2000 (Deiss, 2002), se table 2. The amount of people in Sweden between the ages of 16 and 84 years with access to a personal computer in their homes has risen from 23% in 1994 to 70% in 2002 (SCB, 2004b). One year later in 2003, 80% of the population in Sweden between ages 16 and 74 had access to a computer in their homes (SCB, 2004b), see table 3.

Figure 1 Access to computers



Access to computers has also increased among older adults (see figure 1). In 1994, 4% of the Swedish people aged 65 and older had access to computers in their homes. In 2002, 25% of this age group had access to computers in their homes (SCB, 2004b), see table 3. Within the United States, in 2000, 28.4 % of people 65 years or over had access to a computer in their homes, (Newburger, 2001), see table 1. Thus, handling computers will probably become commonplace knowledge to a large portion of the older population within the coming years; therefore, the demands of designing interfaces with older users' abilities in mind will also increase.

Table 1 Access to computers, Internet and mobile phones in the United States

	1990	1997	2000	2002
Population (65+)				12.3%
Access to computers:				
Age 15+	20 %		59%	
Age 65+			28.4%	
Access to Internet:				
Age 15+		15%	35%	
Age 65+ (in their homes)			12.8%	
Access to mobile phones:				
Subscribers - all ages	2%		40%	49%

Table 2 Access to computers, Internet and mobile phones in the EU

	1990	1997	2000	2002
Population (65+)			12-18%	
Access to computers:				
Age 15+	7%		35%	
Access to Internet:				
Age 15+		5%	24%	53% (43% in their homes)
Age 55+				20% (19% in their homes)
Access to mobile phones:				
Subscribers – all ages	1%		64%	

Table 3 Access to computers, Internet and mobile phones in Sweden

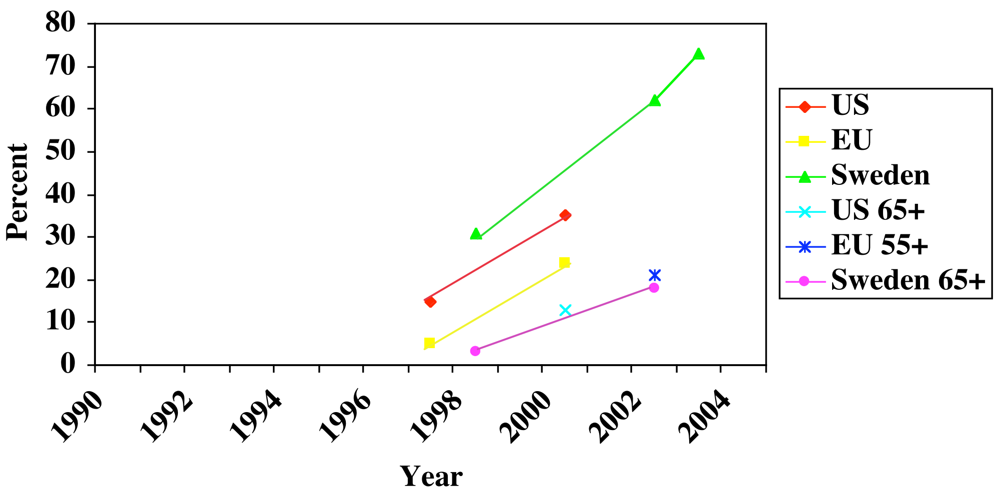
	1950	1990	1994	1996	1998	2000	2002	2003
Population (65+)	10%							17%
Access to computers:								
Age 16-84			23%				70%	80%
Age 65+			4%				25%	
Access to Internet (from home):								
Age 16-74					31%		62%	73%
Age 65+					3%		19%	
Access to mobile phones:								
Subscribers – all ages		5%				72%	87%*	
Age 65-79*				14%			63%	

* Having one in the family

2.1.2. Access to and use of the Internet

The use of the Internet has become more widespread with a growing number of Internet users (see figure 2). In the United States the number of individuals over age 15, who use the Internet, increased from 15% in 1997 to 35% in 2000 (Deiss, 2002), see table 1. Within the EU population, between 1997 and 2000, the number of Internet users over 15 years of age has risen from 5% to 24% (Deiss, 2002). In 2002, the use of the Internet within this group had become 53%, and in 43% of the households they had access to the Internet from their homes (Eurostat, 2003), see table 2. In Sweden, access to the Internet from ones home increased from 31% in 1998 to 62% in 2002 (SCB, 2004b). In 2003, 73% of the Swedish population aged between 16 and 74 had access to the Internet in their homes (SCB, 2004b), see table 3.

Figure 2 Access to Internet

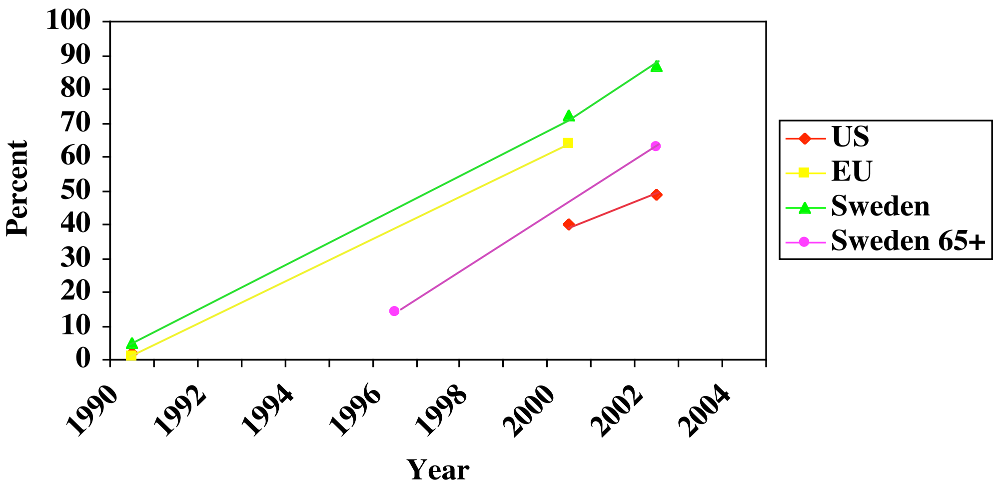


Because the use of the Internet and its new ways for social interaction, older adults have become the fastest growing group of Internet users (Hanson et al, 2001; Morrell, 2001; Morrell et al., 2002). In Sweden, access to the Internet in the home among people aged 65 and older rose from 3% in 1998 to 19% in 2002 (SCB, 2004b), see table 3. Within the EU population in 2002, 20% in the age group over 55 was using the Internet and 19% of this group had access to the Internet from their homes (Eurostat, 2003), see table 2. In 2000, 12.8 % of the population in the United States aged 65 years or over had access to the Internet in their homes (Newburger, 2001), see table 1.

2.1.3. Access to and use of mobile phones

Within recent years, the number of mobile phone subscribers has increased rapidly (see figure 3). In the United States, the number of mobile phone subscribers rose between 1990 to 2000 from 2% to 40% (Deiss, 2002). In 2002 the number of mobile phone subscribers in the United States had increased further to 49% (ITU, 2003), see table 1. Within the EU population, the number of mobile phone subscribers increased between 1990 and 2000 from 1% to 64% (Deiss, 2002), see table 2. In Sweden, the number of mobile phone subscribers rose from 5% in 1990 to 72% in 2000 (Deiss, 2002). Access to a mobile phone (having one in the home/family) for the Swedish population between ages 9 and 79 increased further to 87% in 2002 (SCB, 2003). Mobile phone access (having one in the home/family) among older adults in Sweden rose in the age group 65-79 from 14% in 1996 to 63% in 2002 (SCB, 2003), see table 3. There might; therefore, be an even larger potential to reach older adults through IT-services offered by mobile platforms than through computer and Internet based services.

Figure 3 Access to mobile phones



2.1.4. A worldwide rapid change towards a new large target group

Thus, the older part of the population is living longer and the access to and use of communication devices are becoming more frequent among this age group (figure 1-3). This trend is observable in most of the Western countries (see table 1-3). The growing user group of older adults is a consumer group that are becoming larger and more powerful. This growing user group is one that producers and developers will have to take into consideration much more in the future. This target group will have experience from using different devices and are going to place higher demands on developers in terms of devices that are easy to use regardless of age-related physical and cognitive decline.

The forthcoming older user group is likely to continue the use of computers and other devices into retirement. It is a way to conduct many everyday tasks to which they have become accustomed. They have also become accustomed to having a large amount of applications and services that they can use for different tasks and they are likely to continue searching for applications and services for new tasks that become important or interesting in retirement. Although the experience of technology among older adults in the future is likely to reduce some of the age-related effects due to experience, new products are constantly entering the market and difficulties related to learning new technology will be present. Even if older users have experience from similar applications and devices and/or have high motivation due to having previously been exposed to meaningful and relevant services, the age-related physical and cognitive decline will still affect their possibilities to use new applications and services. Based on these assumptions, it will become more important for companies and developers to take the age-related decline into consideration in the design and development of devices and interfaces.

Furthermore, it is unlikely that the older consumer group will settle with aids or add-on devices to make the usage manageable. This older user group will demand the same access to technology and the same possibilities to communicate with others as other groups in society. They have also, as younger user groups, gained a perspective where new technology conveys identity and; therefore, the outer characteristics of the devices become important. Thus, there will be an increasing demand that new products can be used by everyone and that they are developed in a way that makes them easy to use regardless of the age-related physical and cognitive decline. Knowledge regarding well-established cognitive age-related differences, such as the one in episodic memory (personally related events, connected to specific places and times) (Nilsson et al., 1997), could provide useful insights to the development of new devices and interfaces. This knowledge can contribute to the design process regarding aspects requiring more effort when designing for older adults. It is important that age-related cognitive declines are further investigated, with respect to the use of different interfaces and computer-related tasks. To be able to design usable interfaces is crucial to know in which situations the age-related declines affect the usage and make the older users disadvantaged.

2.2. Opportunities for increased quality of life

The use of computers and the Internet can improve the wellbeing of older adults in several ways. For example, use of the Internet and e-mail can reduce social isolation and increase social interaction with friends and relatives. The access to information and the possibilities to share information with others may increase the feeling of being in control as well as the feeling of integration in society (McConatha, 2002). For example, governmental information is widely available through the Internet, and the use of e-mail provides an easy way to communicate with local leaders within the community (McConatha, 2002) making it easier to influence the community. New possibilities to acquire information and to communicate with others also provide opportunities for older adults to regain some aspects of an earlier lifestyle (McMellon & Schiffman, 2002). Older adults who use computers and the Internet have reported a more positive view on their own ageing (Cody et al., 1999), increased life satisfaction (McConatha, 2002), and feelings of being less housebound (McMellon & Schiffman, 2002). In addition, computer use has been found to provide mental stimulation as well as meeting the needs of fun for older adults (Hendrix, 2000).

2.2.1. Increasing social life

As a result of ageing and retirement social life changes and for many older adults the social network becomes narrower (Östlund, 1999). The contacts with friends and colleagues from work become less frequent and the decline in physical abilities makes it more difficult to meet or visit friends. "One of the primary threats to the physical and psychological wellbeing of older adults is social isolation" (McConatha, 2002, p. 25, see Lemme, 1995). One of the most important issues in reducing social isolation is the existence of social networks (McConatha, 2002). The possibilities to communicate with friends and relatives through computers and the Internet can increase the social network and social isolation can be reduced (McConatha, 2002). Several studies have shown the importance for older adults to be able to communicate with family and friends through the Internet and e-mail (Malcolm et al., 2001; McMellon & Schiffman, 2002; Namazi & McClintic, 2003). Older adults using the Internet have also reported that they experience a higher level of social support (Cody et al., 1999). Another difficulty that older adults are facing is problems related to illegible handwriting, which is a deterioration that occurs in the ageing process (McMellon & Schiffman, 2002). This, in turn, may result in less written communication and less social interaction. By communicating through the Internet or e-mail these kinds of difficulties could be reduced or eliminated (McMellon & Schiffman, 2002). As a result of the ageing process, it becomes more difficult for many older adults to leave their homes due to age-related physical limitations. In these situations computers and the Internet might be especially important in reducing social isolation and fill social needs (Malcolm et al., 2001; Morris, 1994). The increasing possibilities for social interaction through the use of the Internet and e-mail can also contribute to a more active life and to an increasing number of activities of daily living (McConatha, J. T., McConatha, D., Deaner & Dermigny, 1995).

2.2.2. Gaining and exchanging knowledge

As mentioned, it is important for older adults to continue to feel as an active part of society after retirement. One way to achieve this is through the use of information technology and for many older adults this technology is an important area in which to be involved and to gain knowledge (Lindberg, 2002). The conversation about new technology is a common topic among people and there is a need to have some knowledge or experience in order to participate in these conversations. Both knowledge about technology and how to use computers and the Internet can contribute to an increased feeling of integration in society and to a more positive self-perception (McConatha, 2002). Several further aspects may contribute to these increased feelings of integration in the society, for example, the possibility to discuss different topics with others, to exchange knowledge, or to gain new knowledge. One example of gaining new knowledge is through online courses available through different universities. These courses also provide possibilities for people who have recently retired to find new opportunities to continue their working-life (Morrell et al., 2002).

Computers and the Internet also provide new opportunities for older adults to share the knowledge that they have acquired through their lives (McConatha, 2002). Furthermore, it provides opportunities for older adults to gain new knowledge from other generations. The possibility to communicate with children and grandchildren through the Internet and e-mail is important for older adults and is one of the most important reasons for older adults to purchase a computer (Östlund, 1999). Many older adults are receiving help from their children and grandchildren when purchasing and becoming familiar with computers (Östlund, 1999). The use of computers and the Internet is also a topic for conversation with children and grandchildren. One such topic, especially with grandchildren, is the use of different computer games. In studies of computer use among older adults, it has been found that playing games is a computer-related activity in which older adults are engaging (Malcolm et. al., 2001; Namazi & McClintic, 2003) and they are also using the Internet for playing games (Fox, 2001). The use of computer games allows older adults to learn new things (Farris, Bates, Resnick & Stabler, 1994; Weisman, 1983) and to control some aspects of their environments (Weisman, 1983). The use of games is also a means to stimulate social interaction and to improve self-esteem (Farris et al., 1994) and wellbeing (Goldstein et al, 1997). Furthermore, computer games provide the opportunity to have fun (Weisman, 1983), which could contribute to an overall increasing use of computers. It is important for user motivation, and repeated usage of the systems, that users gain positive experiences and find enjoyment in using the systems. For example, Richmond (1996) points out that users who are enjoying themselves are underestimating the time they spend with a system.

2.2.3. Communities for older adults using computers and the Internet

The most common way for people to come into contact with computers and the Internet is through work or at school. However, many people over 65 have already retired and will not come into contact with new technology in this manner. Another way to get in contact with new technology is through relatives, which is a quite common way for older adults to start to use computers (Fox, 2001).

Computer and Internet related technology is constantly changing and it demands that users continue to acquire new knowledge. This makes a technology related social network important, especially for older adults who might be retired and not have access to technical support through work (Ito et al., 2001).

Several organisations for older adults using computers and the Internet have been founded, for example, SeniorNet (http://www.seniornet.org), which is a non-profit organisation that was founded in the United States in 1986 (Ito, O'Day, Adler, Linde & Mynatt, 2001). The aim with SeniorNet is to provide older adults with education about and access to, computer technology (Ito et al., 2001). In 1996 SeniorNet was also founded in Sweden (SeniorNet Sweden, http://www.seniornet.se). Their central idea is "to provide the elderly with a positive environment where they are encouraged to get involved to explore and to enjoy the technology in their own terms" (Männikkö-Barbutiu, 2002, p. 71). At SeniorNet web sites, it is possible to search for information or find topics related to the life of older adults; however, the main focus is on social activity. The community focuses on social exchange among members. They discuss and help each other both with difficulties regarding the use of computers and the Internet as well as other issues

(Ito et al., 2001). Organisations for older computer and Internet users can also provide computer education courses. These courses can have several positive effects besides teaching computer knowledge. They are yet another means to meet new friends and increase social life, which in turn can improve health and wellbeing (McConatha, 2002). In SeniorNet Sweden, all education and training is based upon groups of older adults teaching and helping one another (Männikkö-Barbutiu, 2002). SeniorNet and similar communities contribute to the fact that older adults are becoming more actively involved in the information society, and create places for themselves on the Internet where they have control over the information (Ito et al., 2001).

There is a growing number of web sites with a content directed towards older users, for example, "Thirdage.com" and "SeniorThinking.com" (Morrell et al., 2002). Web sites about health related topics have become quite popular, both with respect to younger and older adults (Fox, 2001; Lindberg, 2002; Malcolm et. al., 2001; McMellon & Schiffman, 2002). In the United States health related issues on the Internet have become so popular among older adults that special web sites have been developed towards this user group, both with respect to content and interface design. One example of such a web site is the "AgePage". It is available through Medline*plus,* a web site that consists of health information from the United States Nation Library of Medicine (Lindberg, 2002). The United States has also several governmental web sites offering information directed towards older adults, on how to make it easier to cope with ageing (McConatha, 2002).

2.2.4. Increased opportunities to live an independent life

Computers can increase the independence for older adults by providing access to information and services (McConatha, 2002; see Czaja, Guerrier, Hair & Landauer, 1993). The use of the Internet makes it possible to search for and book tickets for leisure activities or travel from the home. These new possibilities can contribute to older adults becoming more active in their daily life (Morrell et al., 2002). Further, older adults who suffer from physical limitations can purchase items or groceries directly from the home. Purchasing of products and services (such as groceries and prescriptions) through the Internet could decrease the dependence on other people (Morrell et al., 2002). This will make it possible for older adults to remain living in their homes, and also to do so in a more independent way.

Health is, as mentioned earlier, a very popular topic on the Internet both in general and for older adults. Health information will be even more important in the future both for older adults and to their caregivers (Morrell et al., 2002). Older Internet users are interested in learning both about different diseases and about general wellness issues (Lindberg, 2002). One way of using the health related web sites among older adults is finding answers to health care questions. This information can then be discussed with the doctor, which could improve the perceived quality of the care that is given. Older adults, who have conducted searches on their own before seeing the doctor, have reported that they were more satisfied with their treatment (Lindberg, 2002). The use of the Internet will also, in the near future, make it possible to gain access to other health related services such as making appointments with doctors and asking questions online.

Further topics or issues older adults have reported interesting with respect to computer and Internet use are being able to send and receive e-mail, as well as acquiring information about travelling (Morrell, Mayhorn & Bennett, 2000). Among older adults in Sweden, computers and the Internet are mainly used for e-mail, to find information on goods and services, and to get information from governmental web sites. This Swedish age group also reports use of the Internet for finding information about travelling, and for banking (SCB, 2004b).

The growing use of mobile phones is a further way for communication and for supporting social relations, increasing the opportunities for older adults to live an independent life (Abascal & Civit, 2001). The use of mobile phones makes it easier to arrange meetings with friends and call for help in emergency situations. Older adults, who are using a mobile phone, report a higher level of safety in situations where they earlier have been insecure (Brandt, 1996). The use of mobile phones can be beneficial for older users in many other situations as well, not only for safety and communication. For example, older adults experience difficulties in way-finding, that is, finding their way around within an environment, to a greater extent than younger adults do (Aubrey & Dobbs, 1990) and the development of way-finding services is a growing field. These kinds of services are also a group of services older users have reported that they would find beneficial (Maguire & Osman, 2003).

To summarise, the use of the computers, the Internet and mobile phones can be beneficial for older adults in many ways. The use of the Internet could contribute to increasing social interactions with friends and relatives through the use of services such as e-mail. The Internet also provides the opportunity to gain and exchange information with others via online courses and discussion forums. New opportunities are also arising regarding the possibilities for older adults to remain living in their homes. The use of the Internet for conducting everyday tasks and for shopping can make it possible for older adults to conduct many tasks themselves from their homes instead of being dependent on others. Unfortunately, many older users today are not aware of existing Internet or mobile phone services (Morrell et al., 2002). Many existing services could be useful and relevant for older adults and non-usage is to a great extent based on the lack of knowledge about these services. On the other hand, the increasing focus on older users of mobile phones and the Internet will continue to grow and marketing towards this user group will become more common as this population continues to grow. The up and coming generations will, to a greater extent, have used different services throughout their working-life and they will be able to place higher demands on the companies that provide the services. However, many older adults today are unaware of or do not have access to new technology.

2.3. The Digital Divide

“Digital Divide” is a term that is used to describe differences between those who have and those who do not have access to computers and Internet (Morrell et al., 2002). The differences have been discussed in terms of socio-economic differences, demographical differences, or differences between generations. Even if the access to information technology among older adults has increased, it is less than within other age groups.

Several factors affect older adults' access to and use of computers and the Internet. For example, in the United States many older adults report that they do not have access to a computer and cannot afford to buy one themselves (Morrell et al., 2002). Furthermore, older adults who have access to a computer find many services difficult to use or that the services lack relevance (Shneiderman, 2001).

2.3.1. Motivation

Even though older adults have the same attitudes towards new technology as younger adults (Dyck & Smither, 1994; Kelly & Charness, 1995) and even if they are positive towards learning and using computers, motivational factors are likely to affect usage. After retirement, there is no longer the same demand on people in learning to use new technology. Other aspects of life might become more important than learning to use computer applications or Internet services (Östlund, 1999). Older adults, who are still working and are about to retire within a few years, might be less motivated in learning new technology. This group might feel that they will be able to use their new knowledge only for a short period of time and; therefore, might find it unnecessary to learn new things (Morris & Venkatesh, 2000). Another issue related to motivation is the existence of relevant and meaningful services. Many older adults report not knowing for what they could use the Internet. It will be important to provide this group with information about services that they might find interesting or relevant to raise the motivation of Internet use among older adults (Morrell et al., 2002).

The motivational factors that are affecting the usage of computers and the Internet are of course affecting the amount of experience that is gained. People, who rarely use computers and the Internet, gain little computer experience and might face more difficulties in using the technology due to their lack of experience with the devices and services. However, the age-related aspect of the digital divide has begun to decrease (Shneiderman, 2001) and the use of computers has become more wide spread among different groups of older adults (Morrell et al., 2002). For example, recent studies have showed that other groups of older adults, apart from upper class males, have begun to use computers and the Internet (Morrell et al., 2002). On the other hand, older adults are becoming a less homogenous group and the differences between lifestyles are increasing in this group as well (Östlund, 1999). This places a larger focus on developing interfaces and, besides being easy to use for older adults, it also places demands on taking into account aspects of lifestyle, identity, and belonging. Applications and services have to provide relevant and meaningful content, and they have to provide opportunities to organise and take control over the information (Ito et al., 2001).

2.3.2. Experience with computers

Many older adults have experience from technology use from the time before they retired and their attitudes toward new technology are similar to those of younger adults (Dyck & Smither, 1994). Today's older adults are also familiar with rapid changes in technology and technical devices (Östlund, 1999). However, many older adults report that they lack sufficient knowledge to use the Internet (Morrell, Mayhorn et al., 2000) and they usually face larger difficulties than younger adults in learning and using new computer applications (Kelly & Charness, 1995). The learning process is longer (Kelly & Charness, 1995) and they need more time to solve different tasks (Kubeck et al., 1999; Mead et al., 2000; Sjölinder et al., 2003). Further, with increasing age it becomes more difficult to handle large information spaces, to sort out task-relevant information, and to deal with complex information (Kubeck et al., 1999; Morris & Venkatesh, 2000). Finally, the ability to create an overview of a space or an environment declines with age (Lipman & Caplan, 1992) and it becomes more difficult to navigate large information spaces (Sjölinder et al., 2003).

One interpretation of the differences in performance on computer-related tasks is that older adults have less computer experience (Mead et al., 2000) and less Internet experience (Sjölinder et al., 2003) than younger adults. Several studies also show that older adults have less computer experience than younger adults and that older adults have a greater disadvantage than younger adults by having little to no computer experience (Dyck & Smither, 1994; Kubeck et al., 1999; Mead et al, 2000). The learning process is longer and more difficult for older computer novices than for younger novices (Kelly & Charness, 1995), and the differences in performance between novices and more experienced users are far greater for older than for younger users (Mead et al, 2000).

To some extent, factors related to experience can explain the age-related difference in the use of computers (Kelly & Charness, 1995). However, the age differences in conducting computer-related tasks cannot solely be explained in terms of experience (Czaja & Sharit, 1997). Most cognitive functions decline with age including speed of information processing, attention, working memory (Czaja, 1996), episodic memory (Nilsson et. al., 1997), and spatial ability (Light & Zelinski, 1983; Salthouse, 1982). These age-related differences in cognitive processes might also explain the age differences in learning and performing computer-related tasks (Czaja, 1996).

3. AGEING, COGNITION AND TECHNICAL DEVICES

Even if the age-related differences in technology experience will be less pronounced in the future, the age-related decline in cognitive and physical abilities will remain, and the decline in these abilities will still have an impact on performance with computers and other devices. If computers and other technical devices are going to be used as a channel for information and communication for everyone, the age-related differences and the decline in physical and cognitive abilities must be taken into account when providing new technology intended for all.

3.1. Age-related changes in cognitive functions

Human cognition is described as human information processing and involves processes related to the acquisition and processing of information. The processes that are described as human cognition include: perception, memory, problem-solving, decision-making, and acquisition and use of language (Lundh, Montgomery & Waern, 1992).

Perception is the area that describes how information is achieved through the senses (vision, hearing etc.). Perception processes related to cognition deal with interpretation and/or selection (conscious or unconscious) of information. When people attend to information or conduct different tasks, different levels of attention are required. Depending on the amount of mental effort a task demands, processes related to attention can be more or less controlled or automatic. For example, when conducting a well-learned task such as driving or bicycling, the processes are automatic to a great extent (Lundh et al., 1992), and it is possible to conduct other tasks simultaneously. On the other hand, when the tasks demand controlled processing, it becomes more difficult to conduct several tasks at the same time, due to the limitations in attention and working memory. Working memory has been defined as "an integrated system for holding and manipulating information during the performance of complex cognitive tasks" (Baddeley 2000a, p.78; see Baddeley & Hitch, 1974). Baddeley (1996a; 1996b) describes working memory as a cognitive system consisting of a central executive with two subsystems (the phonological loop and the visuo-spatial sketchpad). Baddeley (2000b) also includes an episodic buffer in the model. This component is related to transfer and recall of information from episodic long-term memory. The (long-term) memory processes includes learning, storage and retrieval. Tulving (1985) has categorized human memory into different subsystems. The memory systems are: semantic memory (learned facts about the world), episodic memory (personal memories), procedural memory (conducting automatic tasks), perceptual representation system (recognition of words and symbols), and prospective memory (remembering things to do in the future). Within memory research, a distinction between explicit and implicit memory has also been made. Graf and Schacter (1985) have defined explicit memory, or explicit memory tests, in terms of deliberate recollection of previous learned materials. Implicit memory, or implicit memory tests, has been defined in terms of absence of deliberate recollection.

Problem-solving is a type of information processing that is conscious. It involves conscious efforts to apply mental processes or to find strategies to solve tasks. This kind of conscious processing is sensitive to cognitive limitations in resources such as working memory and attention (Lundh et al. 1992). Decision-making is another area within cognitive psychology. People make decisions based upon estimations about possibilities related to positive and/or negative consequences. To be able to make these estimations, people use different rules of thumb. These rules involve comparisons between different attributes and their relative values (Lundh et al. 1992). Problem-solving and decision-making have not been in focus with respect to ageing and cognition. However, most cognitive functions decline with age including information processing speed (Czaja, 1996; McDowd & Shaw, 2000), perceptual speed (Morrell & Echt, 1996), attention (Bashore, Ridderinkof & van der Molen, 1997; Czaja, 1996), working memory (Czaja, 1996; Kane & Hasher, 1995), episodic memory (Nilsson et al., 1997), and spatial ability (Light & Zelinski, 1983; Salthouse, 1982).

Processing speed has become more in the focus of studies of ageing and cognition in recent years. Many other age-related cognitive differences may also be explained by the decline in processing speed (Bäckman, Small & Wahlin, 2001; Zacks, Hasher & Li, 2000) and/or by age-related differences in attention (Zacks et al., 2000) and working memory (Bäckman et al., 2001; Madden 2001; Raz, 2000; Zacks et al., 2000).

3.1.1. Processing speed

It is well established that increased age is associated with slower responses and longer reaction times. This association has been shown in several different studies (Czaja, Sharit, Nair & Rubert, 1998; see Cerella, 1990) and contributes to age-related differences in performance on many different tasks. Mental operations are slower for older adults than for younger adults (Hale, Myerson & Wagstaff, 1987; Salthouse, 1993), and processing speed (McDowd & Shaw, 2000) and perceptual speed (Morrell & Echt, 1996) is a component in most age-related changes in cognitive functioning. Processing speed has been suggested to be especially sensitive to ageing (based on a general slowing of neural transmission). The age-related changes in memory and attention may also be explained to a large extent, by the decline in processing speed. The slower processing speed makes it more difficult for older adults to attend to and to respond to different stimuli in the environment, making it more difficult to select, process, and remember information (Bashore et al., 1997).

There has been a controversy regarding whether age-related differences in cognition are best explained by the general factor “processing speed” or by different process-specific factors (McDowd & Shaw, 2000). It has been suggested that the general slowing theory is supported by the increasing age-related difference in performance of complex cognitive tasks. However, much of the research that this assumption is based upon has measured reaction times. Results from other studies show that there could also be task specific or process specific factors involved (Bashore et al., 1997). Even if much of the age-related differences in cognition can be explained in terms of a general slowing, the general slowing theory proposed by Salthouse (1996) has also come to involve process-specific factors in performance of cognitive tasks (McDowd & Shaw, 2000). Much of the research today is using an approach that involves both a general slowing process and specific processes (Birren & Schroots, 2001) related to different aspects of cognition or used when conducting different tasks. Based on this assumption, one important research question becomes to determine to what extent the different processes contribute to the cognitive slowing in performance of different tasks (Craik & Anderson, 1999).

3.1.2. Attention and working memory

It has not been resolved to what extent the general slowing is caused by, or causing the age-related differences in attention. However, attention is an important component in cognitive performance (Madden, 2001; see McDowd & Shaw, 2000) and affects performance of many cognitive tasks (McDowd & Shaw, 2000).

Attention has been described in terms of allocation of resources, or in terms of a central executive that directs other cognitive resources and processes (McDowd & Shaw, 2000). Research shows that the age-related differences in performing cognitive tasks increase during dual task conditions, or during divided attention (Kramer & Larish, 1996, McDowd & Shaw, 2000). The increased demands on memory in attention switching contribute to older adults performing slowly when switching attention between different tasks. However, with respect to attention switching per se, performance does not have do be different between older and younger adults (McDowd & Shaw, 2000). Older adults are also, to a greater extent than younger adults, affected when the primary task is disturbed by performance of a secondary task (Connelly & Hasher, 1993). For example, when attention is drawn away by a secondary task, performance on several memory tasks becomes more sensitive to age-related differences (McDowd & Shaw, 2000). Another explanation to the age-related differences in dual task performance is the decline in the executive functions that direct cognitive resources and processes (McDowd & Shaw, 2000). Furthermore, in some situations the age-related differences in attention has been explained in terms of use of different strategies. For example, older adults use a strategy that narrows down the visual focus or visual search area (McDowd & Shaw, 2000; see Madden & Gottlob, 1997). However, with respect to dual task performance, different results have been found for different tasks and different study conditions; therefore, it is likely that task specific factors contribute to performance as well (McDowd & Shaw, 2000).

Performing several tasks at the same time increases the overall task complexity (Gick, Craik & Morris, 1988; Kramer & Larish, 1996). Older adults face larger difficulties in performing complex tasks than younger adults (Gick et al., 1988, Salthouse, 1992) and age-related differences in performance of cognitive tasks increase when the task complexity increases (Hale et al., 1987; Salthouse, 1993). There are several interpretations of the age-related differences in performing complex tasks. One interpretation is that the general age-related cognitive decline becomes more visible, since complex tasks require critical processes that demand more repetitions. Another interpretation is that the working memory declines with increased age (Gick et al., 1988; Salthouse, 1992) and complex cognitive tasks place greater demands on working memory.

Working memory has been described as an important mediating variable of age-related differences in many different cognitive tasks (Kirasic, Allen, Dobson & Binder, 1996) and the age-related decline in working memory increases with increasing cognitive demands (Bäckman et al., 2001 see Salthouse 1994). The concept of working memory, according to Baddeley (1986), involves both a processing function and a storage function and the age-related decline in working memory is explained by the integration of these two working memory functions. It might be especially difficult for older adults to remember relevant information related to an ongoing task and simultaneously process other information (Salthouse, Mitchell & Palmon, 1989; Craik & Anderson, 1999). This age-related difference can be shown in terms of that older adults have more difficulties in integrating old and new information (Sharit & Czaja, 1994). With respect to complex tasks the demands on working memory increase when the number of operations increase. The material in working memory needs to be preserved, because it will be used in later operations (Salthouse, 1992) and the number of simultaneous operations that require working memory resources also increases (Balota, Dolan & Duchek, 2000).

According to Salthouse (1996), the age-related slowing of cognitive processes reduces the amount and quality of information simultaneously available in working memory or the "dynamic" capacity of working memory (Anderson & Craik, 2000). Tasks that demand more initiative from the user are more difficult for older adults who are less inclined to perform self-initiated processing (Craik, 1983). The importance of working memory (relative to speed) also seems to increase in the performance of tasks that place greater demands on self-initiated processing (Zacks et al., 2000; see Park et al. 1996).

Working memory and attention has also been investigated with respect to the ability to filter out irrelevant information (McDowd & Shaw, 2000). Older adults have more difficulties in sorting out information that is relevant for a certain task (Morris & Venkatesh, 2000). This, the inhibitory view approach investigates age-related decline in working memory and attention based on the inhibition of irrelevant material in working memory (McDowd & Shaw, 2000). Hasher and Zacks (1988) proposed that these inhibitory mechanisms weaken with age and make it easier for irrelevant thoughts and associations to compete for working memory capacity (Balota et al., 2000; Kemper & Mitzner, 2001; Zacks et al., 2000). The age-related inhibitory decline results in an increased amount of task-irrelevant information maintained in working memory (McDowd & Shaw, 2000; see Martin & Ewert, 1997). The age-related decline in attention, working memory and in other cognitive functions has been explained in terms of this decline in inhibitory mechanisms, where inhibition of material that distracts becomes less efficient in older adults (Hasher & Zacks, 1988; Madden, 2001; McDowd & Shaw, 2000).

3.1.3. Memory

Different aspects of memory are affected differently by increasing age. The distinction between memory systems made by Tulving (1985) has provided valuable information regarding the ageing process and how it affects cognitive functions differently. For example, episodic memory is more affected by age than the semantic memory and procedural memory (Bäckman et al., 2001; Balota et al., 2000; Zacks et al., 2000). Episodic memory consists of contextual information regarding source, location, and occurrence of events. One interpretation of the age-related differences in episodic memory is the age-related decline in memory for contexts and sources (Craik & Anderson, 1999). Furthermore, explicit memory has been found to be more exposed to age-related differences than implicit memory (Bäckman et al., 2001; Zacks et al., 2000). There are also age-related differences regarding encoding and retrieval of information and materials. Older adults are less able to conduct resource demanding encoding and retrieval operations than younger adults. For example, self-initiated encoding and retrieval such as generation of novel connections among items or construction of retrieval plans (Zacks et al., 2000). With respect to encoding, older adults are less likely to elaborate memory traces even when they are given instructions to do so (Balota et al., 2000; see Craik & Byrd, 1982). The age differences in retrieval are related to the amount of additional information provided. Strong and relevant environmental support can compensate for the age-related differences in conducting self-initiated processing (Zacks et al., 2000).

3.1.4. Spatial ability and the acquisition of spatial knowledge

The word spatial is defined as ”concerning or existing in space” (Oxford Advanced Learner's Dictionary of Current English, 1992) or ”relating to space” (Collins Dictionary of the English Language, 1986). Overall, the area of spatial cognition could be described in terms of how human beings deal with issues concerning relations in space, navigation, and way-finding. Spatial abilities are cognitive functions that enable people to deal with spatial relations and orientation of objects in space. They also enable awareness of self-location and orientation of oneself in space, relative to other objects and events (Reber, 1985).

In several studies it has been shown that spatial ability influences computer use and the ability to navigate in virtual environments (Benyon & Murray, 1993; Bowman, Koller & Hodges, 1998; Dahlbäck, Höök & Sjölinder, 1996; Vicente & Williges, 1988). Spatial ability (Kirasic, 2000; Light & Zelinski, 1983; Salthouse, 1982, Salthouse, 1991) and spatial memory (Pezdek, 1983; Uttl & Graf, 1993) also decline with increasing age. The age-related decline in memory for spatial information is well established (Craik & Anderson, 1999) and these age-related differences are present both in natural settings (Evans, Brennan, Skorpanich & Held, 1984; Uttl & Graf, 1993) and in artificial settings, such as use of schematic maps (Cherry & Park 1993). Age-related differences in spatial abilities and spatial memory have, to a great extent, been explained by the age-related decline in working memory (Armstrong & Cloud, 1998; Cherry & Park 1993).

A relationship between general spatial ability and learning environmental layout has been found (Kirasic, 2000). Older adults learn and elaborate environmental information differently from younger adults (Kausler, 1994; Nilsson et al., 1997), and acquire spatial information in novel environments slower than younger adults (Kirasic, 1991; Kirasic, 2000). When people engage in spatial learning there are three types of spatial knowledge that is acquired; knowledge about landmarks or reference points, route knowledge, and configural knowledge or survey knowledge (Schacter and Nadel, 1991; Siegel & White, 1975; Thorndyke & Stasz, 1980; Tversky 1993). In a new physical environment, knowledge regarding landmarks is first acquired, followed by acquisition of route knowledge. Route knowledge allows a connection to be made with different landmarks in a sequence and creating a path or a route through the environment. Finally, configural knowledge is acquired and used. Configural knowledge has been defined by Siegel and White (1975) as knowledge about where certain objects are located with respect to other objects in the environment. At this stage, people are able to make judgements about where objects in the environment are located in relation to one another.

In the interaction with physical environments, people rely on their internal representations (Golledge, 1999). The perceptual representation system is involved in the acquisition and use of environmental knowledge and plays a role in the recognition of objects and symbols. This memory system is less sensitive to age than, for example, episodic memory. For older adults, the acquisition of landmarks in the environment is to a greater extent based on personal knowledge and non-spatial associations (Evans et al., 1984; Lipman, 1991). Therefore, older adults are less effective than younger adults in selecting landmarks (Kirasic, Allen & Haggerty, 1992) and it becomes more difficult for older adults to learn the spatial structure of new environments. It has been suggested that age differences in acquisition of landmarks can be explained by the age-related decline in selective attention and to the decline in localization of task-relevant information in the visual field. The decline in selective attention contributes to the difficulties in locating environmental features that could be relevant and meaningful to use (Kirasic et al., 1992). Older adults have lowered performance ability than younger adults on route knowledge tasks (Kirasic, 1991) and have more difficulties than younger adults to place different landmarks in a sequence (Lipman, 1991; Wilkniss, Korol, Gold, Jones & Manning, 1997). The acquisition of route knowledge becomes especially difficult and less accurate for older adults when scenes or landmarks are not presented in a logical order (Kirasic & Bernicki, 1990). Furthermore, older adults have more difficulties than younger adults in using maps or following routes from maps if these are not aligned with their surroundings (if the map is not turned in the same direction as the person's direction) (Aubrey & Dobbs, 1990; Aubrey, Li & Dobbs, 1994). This can be explained by the age-related decline that has been found in the mental rotation component of spatial ability (Berg, Hertzog & Hunt, 1982).

Finally, the most difficult spatial information to acquire and to use for older adults is configural (overview/survey) knowledge (Lipman & Caplan, 1992). The age-related decline in working memory is likely to affect the ability to create configural knowledge because it demands both storage and processing simultaneously (Kirasic, 1991). The age differences in creating configural knowledge manifest themselves in terms of poorer sense of direction and more direction judgement errors among older adults (Aubrey & Dobbs, 1990). Creating configural knowledge demands the use of cognitive processes that place different parts of the environment in relation to other parts or objects within the environment, and the fact that older adults are less inclined to create configural knowledge is also in line with the age-related lack of self-initiation of processing of several cognitive tasks, where older adults' cognitive processes consist of fewer associations and less deep processing of information (Craik, 1983).

3.1.5. Environmental support

Providing environmental support might reduce the negative effects of the age-related decline in cognitive abilities. Environmental support consists of information in the environment that facilitates encoding or retrieval of information and can reduce the amount of cognitive processing that is needed (Jones & Bayen, 1998). One example of this is that older adults may rely more on external memory aids than younger adults and written notes become an important aspect in their lives (Jones & Bayen, 1998).

The amount of remembered information is both dependent on characteristics within the environment and on self-initiated retrieval. Mental processes related to self-initiated retrieval are effortful and become less efficient in older adults. Results from memory research also show that free recall is more affected by age-related decline than recognition, which to a greater extent rely on environmental support (Craik & Anderson, 1999). One of the conclusions from these findings is that older adults are more dependent on the context and on the environmental support than younger adults (McDowd & Shaw, 2000) However, because older adults rely more on the context than on self-initiated processes, they becomes more exposed to distracting material within the environment. If the distracting elements gain too much attention, older adults will face difficulties in continuing task-relevant activities (McDowd & Shaw, 2000).

The spatial memory in older adults can be improved and the acquisition of spatial knowledge can be enhanced by environmental support, but only if this support is provided in an efficient way. For example, it has been found that environmental support for spatial memory is most effective when it is present at the time of encoding for older adults. This suggests that when environmental support has facilitated encoding of spatial memory traces, older adults can rely on their own internal representations for later recall (Sharps & Martin, 1998). In addition, Sharps and Gollin (1988) found that older adults benefit from visually distinctive cues. By providing a coloured map or a three-dimensional model, age-related differences are reduced or diminished.

Finally, it is important to consider whether or not the environmental support increases the cognitive demands, making the cognitive processing too demanding. In those situations the negative consequences might outweigh the positive. It is therefore important to investigate which type of support considered to be useful for different cognitive tasks and to what extent older adults can make use of the environmental support that is provided (McDowd & Shaw, 2000). For example, in tasks that involve searching for information, several ways of providing environmental support is possible. However, it is also important to investigate the extent to which the environmental support actually is of any aid to older adults. It may be the case that these aids are beneficial. On the other hand, they might make the situation more difficult because they increase the amount of information the user has to process.

To summarise, many cognitive abilities are sensitive to changes due to increased age. The age-related decline in processing speed, it has been suggested, explains age differences in several other cognitive functions. Attention and working memory are important components in cognitive performance and affect performance of many cognitive tasks. Age-related differences in spatial ability and in the acquisition of spatial knowledge have also been found. These are age-sensitive skills that are likely to affect navigation in both physical and virtual environments.

3.2. Age-related decline and the use of computers and other devices

Human-computer interaction (HCI) is an area that investigates people's interaction with different types of computing technology, and it involves both the design and the evaluation of systems (Olson & Olson, 2003). "HCI is a multidisciplinary field in which psychology and other social sciences unite with computer science and related technical fields with the goal of making computer systems that are both useful and usable" (Olson & Olson, 2003, p. 491). The use of, or interaction with, computers and other technology can be approached from many different perspectives, for example, investigating user behaviour based on physical and cognitive performance and/or investigating user behaviour based on social context in real world settings (Olson & Olson, 2003). Another approach is to investigate how people come into contact with and begin use of the technology, as well as how they integrate the use of the technology as a natural part of their daily life. Within the area of HCI, several different aspects related to older adults and the use of computers have been investigated. In Männikkö-Barbutiu (2002) this process of appropriation of computers has been described with respect to older adults. All aspects within and around the user affect the user's behaviour and how successful the use of system will be. However, different methods and approaches have to be applied, depending on the questions at hand.

The work within this thesis takes a perspective where aspects of technology use are investigated in relation to human cognition. Other approaches to investigate the interaction with technology are not considered to be less important; however, the main aim focus is on the age-related aspects of computer use that are likely to appear as an effect of decline in cognition due to age. This age-related decline is, at least to some degree, consistent across different contexts and social settings. This decline manifests itself, for example, in terms of older adults usually facing larger difficulties than younger adults in learning and using new computer applications. The learning process is longer (Kelly & Charness, 1995) and they require more time to solve different tasks (Kubeck et al., 1999; Mead et al., 2000; Sjölinder et al., 2003). However, several other aspects, such as physical decline and motivation, may also contribute to age-related differences in performance of computer-related tasks.

3.2.1. Physical limitations

Because, the ageing process is associated with a decline in physical functions, some of the age-related differences in the use of technical devices have been explained by the decline in psycho-motor skills and motor speed (Czaja et al., 1998; Laursen, Jensen & Ratkevicius, 2001; Smith, Sharit & Czaja, 1999; Walker, Philbin & Spruell, 1996). Age-related physical limitations affect the use of input devices and make it more difficult to enter data (Chaparro, Bohan, Fernandez & Choi, 1999; Czaja et al., 1998; Smith et al., 1999). It has been found that the age-related decline in motor control is related to age differences in mouse performance (Smith et al., 1999). Older adults especially have difficulties with dragging and dropping (Namazi & McClintic, 2003), with moving the mouse to the right spot, with clicking on the mouse at the right spot (Namazi & McClintic, 2003), and with double-clicking (Smith et al., 1999). The problems with clicking and double clicking manifest themselves in terms of longer movement times, more sub-movements, and more errors.

The double-clicking task is one of the most difficult mouse control tasks, and it is the mouse control task where age-related differences are most pronounced. Double-clicking is difficult because it demands the user rapidly push the button while not moving the mouse (Smith et al., 1999). In some situations scrolling, can also be difficult. It requires both moving the mouse to a small target and then holding down the mouse button while moving the mouse in the needed direction for scrolling. Chaparro et al. (2000) reported that input devices that rely on the motion of the wrist, such as a mouse, might be especially difficult for older adults to use. Chapparro et al., (1999) compared older and younger adults' in using a trackball or a mouse. In this study; however, no effect related to input device was found. The older adults spent more time completing the movements regardless of input device used. On the other hand, the older adults in the study rated a higher level of exertion than did the younger adults, when using a mouse. With respect to small devices such as mobile phones, buttons are placed close together, and operations that demand much use of the buttons might be especially difficult for older adults. For example, the use of text message functionalities such as SMS is more difficult for older adults to use (Maguire & Osman, 2003), because older users might have difficulties with pressing the correct button at the correct time.

Vision impairments are common among older adults (Jones, Marsden, Mohd-Nasir, Boone & Buchanan, 1999), and after the age of 65, visual acuity deficits become common among many older adults. One example of this is the decline in ability to focus on short distances (Jones & Bayen, 1998). The perception of colours also declines with increasing age (Arditi, 1991) and it becomes more difficult to distinguish contrasts (Arditi, 1991; Craik & Anderson 1999, see Fozard 1990). Depth perception also declines with age (Craik & Anderson 1999, see Fozard 1990) and older adults find it difficult to locate objects in visually cluttered scenes (Craik & Anderson 1999, see Ball & Rebok, 1994). The decline in vision creates difficulties in reading small text on displays and interfaces (Bernard, Liao & Mills, 2001; Ishihara, Ishihara, Nagmach, Hiramatso & Osaki, 2001; Namazi & McClintic, 2003). Regarding the use of mobile phones, both the text in the display and on the buttons are too small for many older users. Reading speed and reading performance in the use of mobile phones are affected by age-related decline in near vision, difficulties with low contrast, and difficulties with short vertical length of characters (Omori, Watanabe, Takai, Takada & Miyao, 2002). In studies of older mobile phone users, the participants have also reported that they have difficulties in seeing the content of the display and in seeing the numbers and letters on the buttons (Maguire & Osman, 2003).

3.2.2. Age-related cognitive decline and computer-related tasks

Many computerised tasks place high demands on cognitive resources. There is a need to find information, to keep track of where information is, and to sort out relevant information. In studies of computer-related task performance the age-related decline in cognitive functions have shown to affect both learning and usage (Czaja, 1996). Processing speed (McDowd & Shaw, 2000) and perceptual speed (Morrell & Echt, 1996) are components in most age-related changes in cognitive functioning and the impact of processing speed is seen as an important underlying factor in attention and working memory capacity.

3.2.2.1. Attention and working memory

Many interfaces or web sites are comprised of a generous amount of information, much of which is unnecessary or irrelevant to complete the desired task. With respect to the use of interfaces and attention, it is important that the user is able to focus the attention on the task at hand. Older adults are affected to a greater extent than younger adults by a secondary task or things within the environment that are disturbing, for example, irrelevant information or cluttered backgrounds on a computer screen (Connelly & Hasher, 1993). Interfaces with reduced information content make it easier to focus attention on relevant information and reduce the time spent on information searches. Aid in focusing the attention can be provided by structuring the information, providing spatial and temporal cues, and manipulating the screen layout (Singh, 2000; see Preece, Rogers, Benyon, Holland & Carey, 1994).

Many computerised tasks place a high demand on working memory (Hockey, Briner, Tattersell & Wietoff, 1989), which has been described as an important mediating variable in age-related differences with respect to computer-related tasks (Czaja, 1996). The age-related decline in working memory affects the use and integration of new information with previous information (Sharit & Czaja, 1994). Many computer-related tasks involve classifying or selecting task relevant information from within a large amount of information. This might be particularly difficult for older adults who have shown to be less inclined to sort out this task-relevant information (Morris & Venkatesh, 2000, Sharit & Czaja, 1994). Excluding irrelevant information or materials from the interface design is one way to reduce the burden on working memory (Singh, 2000; see Preece et al., 1994).

Many information systems are presented using multimedia methods, which are based upon visual, textual, and auditory modalities. Older adults have reported a preference for multimedia systems opposed to text based systems because age-related deterioration of visual ability demands alternative ways of interaction (Ogozalek, 1994). Tardieu and Gyselinck (2003) investigated if the use of multimodal information presentation increases the demands on working memory by creating a dual-task/divided attention situation, or whether it increases the capacity of working memory by providing opportunities to use different subsystems in working memory. The findings from this research suggests that multiple sources of information could be beneficial for learning and usage when the information sources are integrated and when users are encouraged to use them together. Users are capable of working with information from several sources, when the information sources place demands on different components of working memory. However, the usage becomes less efficient if the task or the information sources simultaneously place several differing demands on the same component of working memory (Tardieu & Gyselinck, 2003).

3.2.2.2. Memory

Many older adults have difficulties in learning, remembering, and comprehending different computer commands (Namazi & McClintic, 2003). Function keys might have little relationship to different commands, which place large demands on memory. The use of function keys might be especially difficult for older adults due to the age-related decline in free recall. Menu systems are less demanding than function keys, because the user only has to recognize a command from a list of possible alternatives. Some issues, with respect to ageing and cognition, are likely to be especially important when designing menus for older users. For example, the age-related decline in spatial memory might affect older adults' ability to use the menus because they are spatially organized (Kelley & Charness, 1995). Older adults also have difficulties in remembering the context or the source of the information (Hawthorn, 2000), making it more difficult to remember in which menu a command can be found. Further, older adults have more difficulties than younger adults in remembering the information of an output message if the message is too long. When output messages consist of a large amount of text or information, older adults become confused and remember less (Gregor et al., 2002). These age-related differences can be explained by the sensitivity of age in episodic memory, and an interface that takes age-related differences in memory into account should be designed in such a way that it reduces demands on episodic memory.

3.2.2.3. Spatial ability

People use spatial metaphors when speaking about systems such as the World Wide Web (Maglio & Matlock, 1999). It appears that people bring their understanding and cognition of the real world into understanding the virtual world. The structures of the virtual environments are often designed around spatial metaphors and structures. Several studies have also shown that spatial ability influences computer use and the ability to navigate in virtual environments (Benyon & Murray, 1993; Bowman et al., 1998; Dahlbäck et al., 1996; Vicente & Williges, 1988). The age-related decline in spatial ability and in spatial memory might be one explanation to the increased difficulties older adults face in learning and using computers (Kelly & Charness, 1995). In particular, the spatial visualisation aspect of spatial cognition correlates with several measurements of computer performance (Kelly & Charness, 1995). Spatial visualisation tasks require an integration of spatial information, placing high demands on working memory resources (Salthouse, 1991).

Several differences have been found between individuals with high spatial ability and individuals with low spatial ability. It has been suggested that individuals with low spatial ability have more difficulties in creating a mental model of an environment. Westerman (1995) suggested that individuals with high spatial ability to a greater extent use survey knowledge, and that people who use survey knowledge perform better on computer-related tasks. One way to enhance navigation is to provide a map of the information space, and it has been suggested that both individuals with high and low spatial ability benefit from additional survey knowledge. However, the benefits might manifest themselves in different ways. For individuals with high spatial ability the map makes it easier to take advantage of their abilities. For individuals with low spatial ability the map serves as compensation in terms of providing a perspective of the environment that they would not acquire without this additional information (Westerman, 1995). Verbal contextual information could also be beneficial for individuals with low spatial ability. In situations where the environment is spatial in nature but provides verbal or contextual information, the differences between individuals with high and low spatial ability is less pronounced (Westerman, 1995). Other ways to support navigation for individuals with low spatial ability have been investigated. Stanney & Salvendy (1995) used visual mediators as a means to support navigation. They found that 2D visual hierarchies (all levels visible) and linear structures (open folders with their files presented) were more efficient in supporting individuals with low spatial ability than interfaces where some parts of the information structure were hidden (buttons presenting only main categories). Based on these findings, interfaces that are rich in presenting the structure of the information space may remove the need to mentally construct the environment, which in turn could be beneficial for individuals with low spatial ability (Stanney & Salvendy, 1995; Vicente & Williges, 1988).

3.2.2.4. Navigation

Way-finding has been investigated in several different settings, for example, in real life settings and with map usage. Differing cognitive processes are most likely to be involved in different tasks and settings. However, results suggest that age-related differences in performance on many way-finding tasks are related to working memory and processing speed (Allen, Kirasic, Rashotte & Haun, 2004) or perceptual speed (Kirasic et al., 1992). Older adults are less inclined to create overview knowledge (Lipman & Caplan, 1992) and it appears that they are less inclined to do so in virtual environments as well. In these environments, the difficulties in gaining an overview manifest themselves by older adults requiring more interaction steps to complete information searches. They are also more likely than younger adults to lose track of where they are and return to pages they already visited (Meyer, Sit, Spaulding, Mead & Walker, 1997). The returning to earlier visited pages among older adults has been suggested to be related to the age-related decline in episodic memory (Mead et al., 1999). Older adults also follow more hypertext links and scroll more pages to find the information for which they are looking (Mead et al., 1999).

Many interfaces have deep menu structures, which are difficult to navigate. Older adults more easily get lost in deep menus than in wide menus and are more inclined than younger adults to return to the main/highest level in a hierarchical menu structure in order to regain orientation (Meyer et al., 1997). Moving up and down in the menu structure leads to older adults performing more actions, especially when the menus are deep. It has also been shown that wide menus are more suitable for older adults than deep menus, with respect to both computer interfaces (Freudenthal, 2001) and mobile phone interfaces (Tuomainen & Haapanen, 2003).

When using the Internet, older users have been found to become disoriented in a web site. This confusion reveals itself, for example, by attempts to reach a page where they already are (Chadwick-Dias, McNulty & Tullis, 2003). In addition, older adults have more difficulties in remembering previous actions and remembering the location of information they have already viewed. They select the links they have visited, although the change in colour when the links have been previously visited, and despite being told about the meaning of the colour change (Mead et al., 1999). Many older adults are unaware of which items are clickable; they click on items that are not links such as headings, bullets, and icons more often than younger adults (Chadwick-Dias et al., 2003). These difficulties in knowing which actions to take in order to reach a wanted piece of information are also likely to contribute to confusion in navigation.

Memory for contexts and sources is important in searching the web since there often is a need for finding earlier visited pages. One way of improving the memory for contexts is to provide additional information. For example, Lin (2004) showed that performance could be improved if pictures or animations were provided. Lin also suggested that visual features such as pictures and animation could increase attention and contribute to a stronger motivation, leading to deeper information processing and less disorientation.

3.2.2.5. Information structure and navigation

Hypertext systems such as different web sites make it possible to connect many pieces of information. However, it might lead to large information spaces that are difficult to navigate (Lin, 2003a). Older adults who are browsing and not searching for a particular piece of information, access fewer text nodes and visit more often text nodes that they already have visited than younger adults. These age differences are most pronounced in information structures where the navigation is based on networks, that besides just making it possible to navigate up and down in the hierarchy also provide the possibility to navigate in breadth (Stanney and Slavendy, 1995). The efficiency of other information structures has also been investigated. Westerman, Davies, Glendon, Stammers & Matthews (1995) conducted a study to compare a hierarchical structure consisting of a number of different levels with a linear structure consisting of a list of files. This study showed that both younger and older adults performed quicker with higher accuracy with the linear information structure. The linear structure has been suggested to place fewer demands on working memory and provides environmental support for the task at hand (Rogers & Fisk, 2000). However, the amount of space on a screen is limited. To be able to use a linear structure the amount of information and/or the categories in the structure cannot be too extensive.

Hierarchical information structures, on the other hand, provide the opportunity to organise the information at several levels and in subcategories. Hierarchical information structures have been found to be more efficient for older adults than network-based structures, with respect to navigation, orientation, and browsing. The hierarchical structure, for example, demands fewer steps in reaching the goal than a network-based structure (Lin, 2003a; Lin, 2004; Westerman et al., 1995). It has also been suggested that network-based information structures are more sensitive to differences in spatial ability (Stanney & Slavendy, 1995), a cognitive skill that have shown to be exposed to age-related differences.

A combination of hierarchical and network information structures could be assumed to be beneficial for older adults since it would provide both the spatial organisation and the possibility to navigate in other ways than simply up and down. However, it has been shown that this combination of information structures leads to confusion in navigation and are the most difficult information structures to navigate for older adults (Lin, 2003b).

To summarise the results regarding structure of large information spaces, hierarchical information structures are the most suitable information structures for older adults. With those information structures, it becomes possible to include more information, which is more difficult with linear structures. Hierarchical information structures do not place as high demands on memory and spatial ability as the network structures do. These hierarchical structures are the ones that seem to be most beneficial for older adults since the structures reduce the cognitive load with respect to spatial orientation. The structures also provide support in creating a mental map of the information structure (Lin, 2003a).

3.2.3. Age-related cognitive decline and the use of small displays

Jones et al. (1999) found that users' search performance on small displays was 50% less efficient than on larger displays. The strategies used for information search are different when the screen is small. With smaller screens, the users conduct more scroll activities and more often begin searches by using the search option rather than by navigating (Jones et al., 1999). Although the interface is small, it often provides quite large amounts of information. This could be especially problematic for older adults who have difficulties in handling a lot of information at the same time and sorting out task relevant information (Morris & Venkatesh, 2000). Small interfaces, such as mobile phone interfaces, have limited possibilities to provide an overview information of the space (Zhao, 2001). It has also been found that having a mental map of the menu structure is important for the performance with the device (Ziefle & Bay, 2004). This may present a disadvantage for older users since they have been found to have more difficulties than younger users in creating a mental model of the menu structure. These age-related differences in creating a mental model of the menu structure in mobile phones manifest themselves both in terms of lack of knowledge about the existence of a hierarchical structure (lack of survey knowledge of the environment) and in terms of difficulties in creating a mental representation of a route that could be used to solve a task (lack of route knowledge) (Ziefle & Bay, 2004).

Mobile phones have many complex functions and menu structures that are difficult for older adults to use (Maguire & Osman, 2003). The complex menu structure and its many options can be especially difficult for older users. For example, older mobile phone users have reported that the menu structures are too deep (Tuomainen & Haapanen, 2003). This may indicate that the findings from studies of larger interfaces, where it has been found that wide menus are more suitable for older users (Freudenthal, 2001), are also applicable on mobile phone interfaces. Wide menus might also be especially important for older users since they move more up and down in the hierarchy when they return to the main level to regain orientation (Meyer et al., 1997).

3.2.4. Different tasks, ageing and impact of cognitive abilities

Task performance is of course affected by different cognitive abilities and the impact of these abilities varies based upon the character of the task. For example, spatial ability and reasoning have been found to have a strong impact on text-editing tasks and menu search performance, while visuo-motor skills and processing speed have been found to be important abilities when performing data-entry tasks (Czaja et al., 1998). Different types of computer-related tasks place different demands on the users and their cognitive abilities. When designing interfaces, it is important to take individual differences in cognitive abilities into consideration, both when investigating the sources to the differences and with respect to how these differences affect the performance of different tasks (Czaja et al., 1998; see Egan, 1988).

3.2.4.1. Entering data into records or search fields

When entering data into a record on a computer screen, less amount of work is completed by older adults than by younger and middle-aged adults (Czaja et al., 1998). In a study by Mead et al. (2000) on a library database search where the participants entered data into different fields or conducted searches, older participants had lower success rates and made more errors by entering data into the wrong field. For example, they wrote the title in the field for subject. Age, processing speed, motor skills, visuo-spatial skills, and prior computer experience have been found to have an impact on performance on tasks related to entering data into records or search fields. It has been suggested that the most important underlying factors behind these age difference are the decline in psycho-motor skills and processing speed (Czaja et al., 1998). With respect to data entry tasks that are focusing on speed of responding, it has also been shown that older adults are disadvantaged due to differences in rate of processing and responding (Czaja et al., 1998). Furthermore, experience has not been found to compensate for age-related differences in tasks that are emphasizing speed of processing (Czaja & Sharit, 1997). However, when controlling for differences in work output, older adults have been found to make fewer errors (Czaja et al., 1998).

3.2.4.2. Information retrieval tasks

With respect information retrieval, such as finding answers to questions in different information structures, Freudenthal (2001) investigated navigation in menu structures were the participants had to search for answers to specific questions in a small menu structure. All questions could be answered by pressing a sequence of three buttons in a hierarchical structure. In this study, Freudenthal showed that the overall performance of older adults was slower and movement speed, reasoning speed, and spatial ability had an impact on the overall performance. With respect to conducting the first selection (simple selection), movement speed and reasoning speed were found to have an impact on performance. Regarding steps further down in the menu structure, an increased slowing of performance was found for the older participants and memory and spatial ability measures were found to have an impact on performance. As suggested by Freudenthal (2001), it seems like the increased age differences in steps taken further down in the structure could be related to increased demands on working memory and age-related differences in working memory and spatial ability.

The larger impact of speed of responding (as opposed to impact of cognitive measurements) for the first action taken was also found by Westerman et al. (1995). In this study, reaction speed (menu selection task) was measured as a subtask of an information retrieval task. The results from this study showed that the reaction speed subtask had stronger associations with overall information retrieval measurement than with the different cognitive measurements that were used in the study. Westerman et al. (1995) also suggested that older adults had slower response times. In the same study, with the condition where contextual information was added, significant interactions between age and spatial visualisation and between age and spatial memory were found, showing that older adults with high ability had shorter response times.

3.2.4.3. Virtual environment tasks

"Virtual reality environments are artificial 3D-environments created computationally to either mimic a real environment or to create a novel one. These can vary in their immersiveness. The least immersive would be a 3D-environmnet presented on a computer screen. This could be enhanced by stereo glasses that give a real 3D-experience. Alternatively, the user can wear a head-mounted display for a completely immersive experience" (Olson & Olson, 2003, pp. 498-499). In a virtual reality (VR) navigation study Moffat, Zonderman and Resnick (2001) showed that the age-related differences in performance were present in these environments as well. The older participants spent more time, travelled a longer distance, and made more errors in terms of revisiting an earlier visited dead end. In this study, performance measured by time spent was positively correlated with measures of mental rotation and verbal and visual memory (Moffat et al., 2001).

A virtual environment is considered to provide semantic mapping when the distance in the virtual environment matches the users mental model of the semantic content, in other words when items considered to be very different are placed far away from each other in the virtual environment (Westerman & Cribbin, 2000). When 3D-environments lack semantic mapping, the navigation becomes more cognitively demanding than navigation in 2D-environments. On the other hand, when semantic mapping is applied in the 3D-environment, navigation is facilitated. However, the benefits must outweight the additional cognitive demands related to navigation in these environments (Westerman & Cribbin, 2000).

3.2.4.4. Task complexity

Many tasks that are performed with computers are complex both in terms of activities to be performed and in terms of cognitive processes that are needed. The relation between ageing and task complexity is an important factor when studying older adults and their use of computers and Internet services. Older adults face larger difficulties in performing complex tasks than younger adults for both cognitive tasks in general (Gick et al., 1988, Salthouse, 1992) and for computer-related tasks (Freudenthal, 2001; Kubeck et al., 1999; Sjölinder et al., 2003). For example, when navigating in a menu structure the age-differences in response times increase for each step taken, because every additional step is adding complexity to the task (Freudenthal, 2001). Performing several tasks at the same time also increases the overall task complexity (Gick et al., 1988; Kramer & Larish, 1996) and there are large age-related differences in dual task performance (Kramer & Larish, 1996).

Task complexity is also related to how familiar the user is with the task or the information. There is a trade off between how much information that is needed to complete a task versus providing too much information, which in turn increases the complexity. When the information is familiar, it can be represented and understood without additional information. On the other hand, when the information is unfamiliar, it becomes more important to provide support or more additional information (Ji & Salvendy, 2001).

3.2.5. Training and acquisition of computer skills

Training and experience partially explains the age-related differences in performance of computer-related tasks. Older adults face larger difficulties than younger adults in learning new computer applications (Kelly & Charness, 1995). Learning computer-related tasks is slower (Hendrix, 2000; Kubeck et al, 1999; Mead et al, 2000), the learning process is longer (Kelly & Charness, 1995), it takes more trials to acquire a particular skill (Hendrix, 2000), and older adults reach poorer final levels of performance than younger adults (Kubeck et al, 1999; Mead et al, 2000). Training regarding computer-related tasks and the use of interfaces has been shown to be successful for older users (Rogers & Fisk, 2000). Experience of computers is important for older users. When learning new computer-related tasks, younger adults with high computer experience perform slightly better than those with low experience. On the other hand, older adults with some computer experience perform much better than those with no computer experience (Mead et al., 2000).

Older users are more cautious in the interaction with computers and interfaces. They spend more time reading information and thinking about possible actions before clicking on links and buttons (Chadwick-Dias et al., 2003). This type of behaviour might be explained by the lack of knowledge about the consequences of different actions and by their efforts in trying to understand those consequences before doing anything. When the older adults take their time reading instructions, they acquire knowledge about different actions and consequences. Training has also shown to positively affect older adults' confidence in using computers (Lindberg, 2002). One further positive aspect for older adults is learning can be adjusted to each individual's abilities and presuppositions with computer use (McConatha, 2002).

There is a large amount of training programs, and material could be presented in many different ways, for example, as written manuals or visual multimedia tutorials (Fisk & Rogers, 2002). Older adults' performance is, to a large extent, affected by the type of training provided and the way the instructions are presented. For example, older adults perform less well than other groups when they have been trained through reading a manual (Fisk & Rogers, 2002). On the other hand, video training has been found to be efficient for older adults with its benefits remaining over time. Video training provides environmental support in terms of presenting task sequences explicitly. This support reduces the demands on working memory in terms of providing visualisations and with respect to reading comprehension, because fewer inferences have to be drawn (Fisk & Rogers, 2002). Multimedia-based instructions have shown to be the most efficient training for all age groups. This way of presenting instructions contributes to a reduction in perceived cognitive load, especially for older adults (Van Gerven, Pass, Van Merriënboer, Hendriks & Schmidt, 2003). However, when using multimedia-based instructions, it is important that the different information sources are well-integrated, otherwise the learning might place too high demands on mental integration of the content (Mead et al., 1999).

3.2.5.1. Training methods

With respect to training methods, task training and practice are important (Czaja et al., 1998). Hands-on training that provides active self-paced training is especially beneficial for older adults (Jones & Bayen, 1998; Mead et al., 1999; Rogers & Fisk, 2000). One advantage of action training is that it relies predominately on procedural memory, which is less sensitive to ageing than episodic memory (Mead et al., 1999).

Interactive training on navigation methods can reduce the need to start searches from the main level (Meyer et al., 1997). Another way to support learning is to provide opportunities for discussions between users. Discussing difficulties with other users could enhance deep processing of information and, thereby, contribute to newly learned material being better remembered (Jones & Bayen, 1998). The importance of enhancing different cognitive processes or reducing the cognitive demands on others has been pointed out. For example, Morrell and Echt (1996) suggested that the most efficient training seems to be training that reduces the demands on age-sensitive cognitive processes such as working memory, text comprehension, spatial ability, and perceptual speed. The demands on these cognitive processes could be reduced by writing instructions in a simple language, provide illustrations to the text, and provide online tutorials (Morrell & Echt, 1996).

3.2.5.2. Instructions

Simple step-by-step instructions facilitate learning for older adults (Morrell, Park, Mayhorn & Kelley, 2000). The age-related differences in text comprehension tend to be much less pronounced when the instructions are simple (step-by-step). When the instructions are more complex, e.g. both step-by-step instructions and information to conduct procedures, older adults are disadvantaged to a greater extent (Morrell, Park et al., 2000). Several factors affect learning and in order to design efficient training programs knowledge about the domain, material, and tasks is important. Different training approaches should also be applied at different points in training (Mead et al., 1999).

3.2.5.3. Training sessions

It is important that the training is provided at an appropriate level. To keep the learner's interest, training has to be challenging, as well as uncomplicated (Cody et al., 1999). The learning process is longer for older adults; therefore, it becomes even more important to provide enough time to process information. Teaching pace should be individualised to older adults, because they benefit from self-paced training. Furthermore, it is important that the training allows the learner to make errors while providing support in dealing with these errors. This might be especially important for older adults, since they do not engage in self-initiated processing to the same extent as younger adults (Kelley & Charness, 1995). Finally, it is important that the learning sessions provide opportunities to ask questions, because older adults request more help than younger adults (Jones & Bayen, 1998).

Training is important to older adults, because it affects to what extent they will continue to use computers (Morrell, Park et al., 2000). Even computer applications and interfaces that are well-designed require training (Fisk & Rogers, 2002). As discussed by Rogers and Fisk (2000), it is important to know when to apply design improvements and when to apply training solutions, because the impact of the interaction between ageing, cognition, and learning varies between different systems.

To summarise, the age-related decline in many functions affects the use of computers and other devices. The ageing process is associated with decline in physical functions, for example, psycho-motor skills and vision, which makes it more difficult to handle the devices or see the content of the displays. The age-related decline in cognitive functions affects the ability to attend to, select, and make use of information presented in different interfaces. Because of the age-related cognitive decline it also becomes more difficult to navigate large information spaces, and to find the desired information.

3.3. Devices and interfaces for physical and cognitive limitations

A common viewpoint is that “design for all” and interfaces that are designed with older adults’ presuppositions taken into account will result in interfaces that are acceptable and easy to use for everyone. However, users both within the same age group and between age groups are very different and their needs and presuppositions may vary between different situations. Hawthorn (2003) discussed the difficulties with the “design for all” approach in general and in particular to older adults. Hawthorn argues that when designing interfaces for older adults, it is not clear which features to avoid since it is a very diverse group in terms of physical and cognitive capabilities. Based upon the “design for all” approach, the design needs to take a variety of different deficits (and combinations thereof) into account, resulting in a design that might address the needs of few users, while disregarding the rest of the users. Hawthorn also stated that it is difficult to find a balance between keeping an interface simple and providing enough functionality for more advanced users. For example, older adults tend to reject functionalities that are considered to be very important for some other user groups. The solution to this problem is to provide functionality that makes it possible to turn on and off different features. However, older users also have difficulties with both turning off functionalities and with turning on the accessibility features that might be available (Hawthorn, 2003).

Research has focused on the difficulties in taking into account the needs and preferences of different user groups. The focus has been on the dynamic changes within user groups and within individuals, and also on making the use of the interfaces and the adjustments of the interfaces easy for different user groups. Approaches and methods addressing these issues are described in the following discussion, along with targeted efforts or systems that address one or a few specific needs.

3.3.1. Dynamic diversity and adaptive interfaces

Physical and cognitive functions decline with increasing age, affecting each individual differently. With respect to capabilities, there are large variations between individuals. Among older adults these variations grow even larger. There are also variations within the same individual, where the individual’s capacity varies between different situations depending on, for example, social context, life situation or illness (Gregor et al., 2002). During the last years, the dynamically changing needs related to the ageing process and the use of information technology have been placed more in focus. It has been suggested that the design and the design process need to place a larger focus on this “dynamic diversity”. The ageing process makes the use of the devices constantly changing; therefore, interfaces have to be designed to be adjustable or adaptable to this change (Gregor et al., 2002). In the last years, it has become more important to develop both interfaces and design methods that take the ever-changing ageing process into consideration.

3.3.1.1. Getting information about the user

To be able to adapt to different users and their abilities, the systems must get information about the user, for example, by asking questions or by drawing conclusions based on user behaviour. Seiler, R. J., Seiler, A. M., Ireland, Guy, and Woodward (1998) developed a system that assessed information about the users. The system collected data about skills related to vision and physical functions, as well as language and cognition in the use of the Internet. The aim with the system was to introduce the Internet to older adults with physical or cognitive disabilities or to people who were unfamiliar with computers and the Internet. While the system introduced the Internet and concepts related to Internet usage step by step, it also collected data about different user abilities. For example, visual memory in terms of assessing ability to remember icons and symbols and reading comprehension in terms of understanding single words and complex sentences.

3.3.1.2. The use of different interaction modalities

One way to increase flexibility and to design more accessible interfaces is to provide interaction in several different ways. This can be achieved by supporting different input devices or using different modalities for interaction (Fernandes, 2001). Multimodal interfaces provide the opportunity to use several different input modes at the same time or to switch between different modes (Fernandes, 2001; Xiao, Lunsford, Coulston, Wesson & Oviatt, 2003). These interfaces make it possible for the user to choose the most suitable modality with respect to task, preferences, or abilities (Xiao et al., 2003). In a study by Xiao et al. (2003), older adults' interaction with a multimodal system using speech and pen input was investigated. This study showed that it was possible to classify older adults in the same way as children or younger adults. The older adults were also consistent in their interaction, and they interacted in a way that made it possible to make predictions relatively quickly. However, Xiao et al. found larger individual differences among the older adults. The older adults were also more inclined to engage in self-talk than the younger adults, which might have an impact on design and use of multimodal systems because these systems have difficulties in distinguishing self-talk from intentional input to the system.

3.3.1.3. Adapting the information content

It is not only the interface that has to be easy to use. It is also important that the information content is accessible and relevant with respect to different user needs. The information need could vary to a great extent between different user groups. Certain user groups might have specific information needs and demand additional information regarding certain issues. For example, people with physical disabilities need to know where the elevators are located in a building (Kobsa, 1999). To solve the problem of receiving irrelevant information or wrong information, the information presented could be adapted to each individual's information need (Kobsa, 1999). Fink, Kobsa and Nill (1998) have suggested different ways to adapt the information; for example, by providing blind users with more details about orientation and the possibility to use audio or tactile output, or to provide wheelchair-bound users with more information about accessibility of buildings, such as where elevators and ramps are located.

In Fink et al. (1998), the development of an adaptive interface is described. The aim with the system was to adapt the content and the presentation of web pages to each individual user's needs. The system made predictions about the user's information needs based on initial interviews, navigation history (which information the user previously found interesting), and predefined assumptions/stereotypes about certain user groups. The users could also select different roles, such as "blind", "wheelchair", or "walking around". The evaluation of the system showed that the motion-impaired users were more satisfied with the system and the information content than the able-bodied users. The able-bodied users found that there was not enough information provided for their purposes (Fink et al., 1998). These results show the importance of providing relevant information for all user groups. If only users with special needs find the systems meaningful to use, it will lead to design of systems for people with special needs instead systems or interface for all. Again, the discussion regarding the difficulties in designing systems and interfaces for all in Hawthorn (2003) seems relevant and worthwhile.

3.3.2. Physical limitations and aiding devices or software

Several aspects of the physical age-related decline affect the use of computers and other devices. However, several applications or functionalities have been developed to compensate for this decline and to make the interfaces possible to use for people with physical limitations.

3.3.2.1. Vision impairments

Older adults tend to prefer larger text size, although text size has not been found to affect performance (Chadwik-Dias et al., 2003). For users with reduced vision, the size of the curser (Namazi & McClintic, 2003) or the items and letters can be increased to make the interface easier to use. Regarding the use of the Internet and web browsers, it is possible to make changes such as font colour, or avoid flashing elements (Hanson, 2001). Software for web authors can support the possibility to create alternative versions of web pages; for example, versions that are more readable to users with low vision or adjusted for use with screen readers (Hanson, 2001).

Screen magnifiers and talking browsers can help users with visual or reading disabilities (Hanson, 2001). A number of companies are providing screen-readers for visually impaired users. However, several challenges have to be faced within this area because these tools have to understand which information the user wants to attend to (Olson & Olson, 2003). Other systems provide speech output as one way of interaction. These systems are developed and based upon analyses in how to present the information and what type of voices are most liked and trusted among different user groups (Lines & Hone, 2002; Zajicek, Lee & Wales, 2003). Overall natural non-synthetic male voices are perceived more positively than other combinations of voice characteristics (Lines & Hone, 2002).

3.3.2.2. Motor impairments

One way to facilitate interaction for motion impaired users is to increase the number of interaction channels (Hwang, Keates, Langdon, Clarkson & Robinson, 2001). Users that face difficulties when interacting with a mouse could be helped by the use of mouse keys (Hanson, 2001) or by the use of a keyboard emulator, which is a tool that shows a representation of a keyboard on the screen containing keys that can be selected (Hwang et al., 2001). Some of the difficulties that motion impaired users face could be reduced by a more efficient use of existing input information. By interpretation of input data and input behaviours, systems can respond in a way that is appropriate to user needs. For example, when a user has difficulties in using the mouse to place the cursor on an icon, the interface could respond by enlarging the icon (Hwang et al., 2001). The interaction conducted by a mouse could also be made easier by reducing the sensitivity of the mouse (Namazi & McClintic, 2003). Walker, Millians, and Worden (1996; as described by Rogers & Fisk, 2000) developed an adaptive interface using interaction with a mouse. This interface was adjustable and allowed the older adults to compensate for their increased motor noise. Finally, interaction help could be provided for motor impaired users by making the existing interaction channels richer. For example, haptic feedback could contribute with the feeling of bumps and edges when the mouse passes over items or boundaries on the screen (Hwang et al., 2001).

3.3.3. Cognitive limitations and aiding devices or software

There is an extensive amount of literature that provides design recommendations based on general research literature on ageing. Far less work has been conducted regarding designing systems and interfaces that meet the needs and preferences of older users. However, some examples of systems that have been designed with older adults in focus are described below.

To be able to use an e-mail system efficiently, many users demand several functions that are quite complicated to use. In an e-mail application, older adults have difficulties with saving attachments, finding files, attaching files, and sending them. All these functions are basic functions of an e-mail system; however, the user needs to understand and navigate a complex information structure (Hawthorn, 2002; described in Hawthorn, 2003). With respect to older users and usability of e-mail systems, Hawthorn has pointed out the importance of finding a balance between simplicity and the need for basic functions. Hawthorn has also developed an e-mail system that, among other things, aimed at reducing the complexity. The information structure in the system developed by Hawthorn was linear and consisted of few options. Fonts and controls were increased and the amount of scrolling and window management was decreased. The difficulties older adults are facing regarding saving attachments were solved by an additional folder called "My Attachments", where the attachments were saved as default. The difficulties older adults are facing with respect to finding and sending attachments were solved by numbered instructions guiding the user through the task. Another difficulty for the older users, revealed in the study by Hawthorn (2003), was to organize and find files in personally classified folders. Due to the decline in long-term memory it becomes difficult to remember in which folder a document has been placed. Hawthorn suggested a solution to this problem by using a number of predefined folders. An option was available where the users were given the alternative to place items into categories when transferring them from the inbox to the saved e-mails.

Chadwick-Dias et al. (2003) developed a prototype aiming to make interaction easier with respect to age-related cognitive decline and difficulties in navigation. This was achieved by using action word links such as *Go to* to reduce cautious clicking, by marking visited links in a consistent way, by making icons and bullets into links to reduce the clicking on non-links, and by reducing unnecessary text (because older adults are more likely to spend more time on reading all the text on a page). Older adults have more difficulties with respect to orientation. In the system developed by Chadwick-Dias et al. (2003), an explanatory text was added to make the present location more self-evident. In the evaluation, it was found that performance with the system was better than that of a similar system that had not done any adjustments towards older users. However, the performance increased for both younger and older participants and the age difference remained. On the other hand, it is likely that older adults in most situations will achieve lower levels of performance than younger adults. It is not self-evident that the only aim with the design should be to eliminate age-related differences. Instead, by providing interfaces that improve performance for all user groups, the access to technology will become easier for everyone. The overall aim in focusing on different user groups with specific needs, with respect to interface design and interaction, is to avoid their exclusion from the information society; rather than trying to eliminate differences between users and user groups. It is also important to consider which aspects, related to performance, are important. Qualitative and experiential values and measurements are as important as performance measured by, for example, time spent or efficiency.

Based on the "Designing for diversity" approach, Gregor et al. (2002) implemented a system with the aim to enhance performance for users with memory deficits or vision impairment. The system provided functionalities such as being able to choose speech as output, seeing the text enlarged, or providing messages regarding the state of the system and the next step to take. The system also had a help function, where a voice was leading the user through the interaction with the interface. The help system could be switched off when the users decided that they no longer needed it.

There are also systems and algorithms dealing with people's limitations in time and working memory. Jameson, Schäfer, Weis, Berthold, and Weyrath (1999) conducted work regarding systems that adapt to temporary limitations of the user's available time and working memory capacity. Jameson et al. (1999) also developed a system that focused on predicting and controlling the processing time of the user. For example, the system was using input on simultaneous tasks that needed to be completed, latencies in understanding, and response to questions. However, there are many contextual and behavioural aspects to take into consideration when designing these types of systems that are based on complex structures mirroring human performance.

3.3.4. Recommendations and guidelines for interface design

To make web pages easy to use for older users, both general design guidelines and guidelines targeted towards older users should be taken into consideration. There exist a number of general guidelines and tools that can be used to make web pages accessible. The World Wide Web Consortium (W3C), the Web Accessibility Initiative (WAI), and the Web Content Accessibility Guidelines (WCAG) have provided guidelines for accessible web pages[1]. There are also tools and organizations auditing web pages for accessibility, for example, Accessible Web Authoring Resources and Education Centre (AWARE)[2] and the Centre for Applied Special Technology[3], provide a service for testing web sites for accessibility (Echt, 2002). However, much material on accessibility covers many different disabilities, not only the specific needs of older user groups. With respect to older users and the age-related decline that might affect the use of interfaces and web pages, the U.S National Institute on Aging has provided guidelines for designing web sites based on the specific needs of older users (National Institute on

[1]http://www.w3c.org
[2] http://aware.hwg.org
[3] http://webxact.watchfire.com

Aging, 2002). There also exists literature reviews on accessibility recommendations for older users (for example, Echt, 2002; Holt & Morrell, 2002; Morris, 1994) or for users with memory limitations (Singh, 2000).

There is quite some work on design recommendations that meet the needs of older users. Some of the recommendations have been investigated and tested in the design of interfaces and some of the work makes conclusions based on previous research about different aspects of ageing and age-related decline. Below are a few examples of suggested recommendations related to ageing and cognitive decline presented.

3.3.4.1. Presentation of information

Several methods for focusing attention at the interface have been suggested, for example, structuring information, providing spatial and temporal cues, and manipulating screen layout and colour (Singh, 2000; described in Preece et al., 1994). The demands on working memory can be reduced by allowing the user to process concrete representations of items instead of being forced to rely on working memory (Hawthorn, 2000). By providing environmental support, the demands on working memory can be reduced (Mead et al., 1999) and environmental support can make the use of web sites easier for older adults. For example, the applications should provide cues to support recognition by providing different options to choose, instead of relying on free recall (Hawthorn, 2000). Furthermore, environmental support could provide support for context encoding and recall. More salient markers of previously followed hypertext links and more perceptual cues, such as colour coding or graphics, could be used to create associations with the information content (Mead et al., 1999). By providing indexes to where information can be found, the age-related difference related to memory for context can be reduced (Hawthorn, 2000). By providing opportunities to enhance elaboration and deep processing of information and/or navigation structure, more associations to the material will be created, and it will become easier to find the wanted information. One way to achieve this is by using several different ways to attend to and remember information; for example, by using different modalities or by presenting several different cues that relate to the material (Kelly & Kroemer, 1990). Finally, the use of environmental support such as reminders may be especially helpful to older users; it could provide help regarding actions that need to be conducted (Singh, 2000).

Users with memory deficits may have difficulties with large amounts of information (Singh, 2000). Different approaches can be used to reduce the amount of information. For example, the content of the documents can be modified (Singh, 2000) or information can be sorted and presented based on user preferences or user navigation history. With this solution, the information or the documents are presented in an order that is most likely to be relevant to the particular user. In these recommender systems, users get a set of items recommended based on how similar their preferences are to other users' preferences (Konstan et al., 1997; Svensson, Höök, Laaksolahti & Waern, 2001). Recommender systems aggregate the behaviour of many users and then group their choices. Based on this grouping, the system then recommends items to individual users. If, for example, person A, B, and C have bought the same three books on the web, book 1, 2 and 3, and person D has bought book 1 and 2, the system will recommend book 3 to person D. With respect to users with language limitations (difficulties with connecting objects and actions to the words that are describing them), Singh (2000) suggested that concepts should be represented visually, using icons in the representation of main categories.

3.3.4.2. Navigation

The organization of a web site should be simple and straightforward. A standard page design should be used, and the same symbols and icons should be used throughout the entire web site. Each page should also be labelled with the name of the web site, and this label should be placed in the same location on all pages (National Institute on Aging, 2002). The same set of navigation buttons should be used, and these should be located at the same place on each page. Explicit step-by-step navigation should be provided so that the users understand what follows next (National Institute on Aging, 2002). Navigational aids such as maps (Morris, 1994; National Institute on Aging, 2002) and/or fisheye views should also be provided to orient the user (Morris, 1994). Simple navigation that provides redundant navigation information could also help older users, since the redundant cues make it easier for older adults to remember where they are and where they have previously been on the web site (Chadwick-Dias et al., 2003). Navigation that is based on recognition strategies is more efficient for older adults than navigation based on free recall. Menu based navigation is one way of providing cues for recognition, since the commands in the menus are items that could be recognised (Morris, 1994). When the menus are deep or nested, they become more difficult to navigate. It will then become more difficult to remember where in the menu structure different options are located. Older adults are also, as mentioned, more disadvantaged when the menus are deep, since they are more inclined to return to the main level to regain orientation (Meyer et al., 1997). Based on these findings and on the demands that deep menu structures place on working memory and spatial ability, Freudenthal (2001) suggested that deep menu structures are less suited for older users. On the other hand, too many menu options in a linear structure leads to much information being presented at one time and creates a complex environment. In those situations it will be important to reduce the number of functions provided (Zajicek, 2001).

History-based tools or navigation aids that are showing previously visited places or previously used information contribute to reducing the memory load, regarding both working memory and long-term memory (Ji & Salvendy, 2001). Older adults have difficulties in recognising links. Therefore, it is important that links and previously visited links are designed in a consistent way. Older adults would benefit from links that provide visual feedback on mouse-over (Chadwick-Dias et al. 2003). Many older users are confused with respect to bullets and buttons. Older adults think that list bullets are navigation buttons that are clickable, which is often not the case. To avoid older adults making this mistake, icons and bullets should be made into links as well. By providing several different ways to reach a destination, the likelihood of older adults reaching their target increases (Chadwick-Dias et al. 2003). When icons are used as links, an explaining text should also be provided to facilitate the understanding of the action that takes place when the user clicks on the icon (National Institute on Aging, 2002). Finally to facilitate navigation for older users, buttons such as “Previous Page” and “Next Page” should be included in the design to make it easier for the user to go back or move forward within the environment (National Institute on Aging, 2002).

3.3.4.3. Warnings

One important aspect of interface design for older users is to consider how the age-related decline affects the ability to perceive and understand warnings or important messages. The decline in working memory may lead to forgetting warnings or placing them in the wrong context (Rousseau, Lamson & Rogers, 1998). The age-related decline in prospective memory makes it more difficult for older adults to remember warnings that are given in advance (Rousseau et al., 1998). Finally, the reduced ability in comprehending complicated texts or in comprehending symbol information makes it less likely that older adults will act on complicated warnings or different symbols (Rousseau et al., 1998). Rousseau and Rogers (1998) suggested design recommendations that will make warnings easier to attend, perceive, or remember by older users. For example, memory cues that make it easier to remember warnings should be provided, warnings or reminders should occur when an action is required and not in advance, and text should be written with simple explicit sentences. When using symbol information, the comprehension should be tested and evaluated (Rousseau et al., 1998).

3.3.4.4. Applying the guidelines

Accessibility guidelines can be applied automatically. In the work described by Hanson (2001) a system was developed that transcoded web pages according to user-specified preferences and capabilities. Before the web pages were presented on the computer screen, a server re-formatted the content based on user specifications about how the web pages should be presented. A software system provided the user with the possibility to select relevant transformations, and the transformations were completed on a server. This approach or this solution does not require that the users constantly keep up with changes in the technology since the transformations are conducted on a server and not on the user's computer.

Mughal & Zaphiris (2003) have investigated to what extent different web sites meet the existing recommendations and guidelines for older users. In their study, the recommendations and guidelines were categorised in five subgroups: vision, psycho-motor abilities, attention, memory and learning, and intelligence and expertise. Mughal & Zaphiris (2003) found that all web sites, which were included in the study, met over half of the guidelines and that violations of cognitive abilities such as attention, memory, and learning were less common than violations related to decline in vision. Mughal & Zaphiris thereby provided a good starting point for actually investigating the implementation of guidelines for older users. However, only a small number of web sites were investigated and the focus seemed to be more towards the decline in different aspects of vision than in different aspects of cognition. Another study, conducted by Becker (2004), investigated to what extent the guidelines provided by the National Institute on Aging were met by different kinds of web sites in the United States offering health resources. The investigated web sites belonged to one of four categories: governmental, commercial, non-profit, and newspaper. The study by Becker examined guidelines regarding design, content, performance (measured by downloading times), and language. Only a few guidelines related to age-related cognitive decline were examined in this study; however, one guideline regarding navigation was included in the study. The guideline regarding the presence of a site map was only met by 12% of the commercial, 32% of non-profit organizations, 44% of newspapers, and 56% of governmental (Becker, 2004). In the study by Becker, the number of included web sites was quite large and it consisted of different kinds of web site providers. However, more work has to be conducted with respect to the implementation of guidelines and recommendations that are related to the decline in different cognitive aspects and to the age-related differences in navigation.

3.3.5. Software designed to train cognitive abilities

Cognitive abilities need to be used and trained. Specific cognitive training can improve memory, reasoning, attention, and visual perception for older adults. However, the improvements are often task specific and do not transfer to other areas or tasks (Fillit et al., 2002). Furthermore, the training must be maintained, otherwise the cognitive improvements may begin to decline. One important factor to be able to maintain and use newly gained or trained abilities is an active life style. Based on this Willis (1989) suggested that, if the positive effects of training should remain, individual cognitive training should be adapted to the individual's life style. One example of a system that was developed to meet the life style and interests of older adults was Nostalgia. It was a prototype that could be used for listening to old news and music from the twentieth century. The design of Nostalgia was an attempt to design an artefact that could trigger the memory of past events, both individually and in the company of others. The prototype consisted of an interactive textile runner and of an old fashioned radio placed on a table. The runner was divided into sections that represented decades. The users could then interact with the system by pressing somewhere on the runner. A press on the runner represented a choice of news or music (Nilsson, Johansson & Håkansson, 2003).

Besides for entertainment, the use of computer games can provide opportunities to improve both psycho-motor skills and perceptual/cognitive skills. For example, games have been developed for children with ADHD (Attention Deficit Hyperactivity Disorder). The aim with these games has been to provide an environment that supports training with respect to working memory and attention. These games have also been marketed towards patients with brain injuries or stroke patients that suffered from deficits in working memory (Cogmed, 2006; Kämpfe, 2002). For older adults the use of computer games can affect performance on different cognitive tasks. Video games have been found to improve older adults' reaction time (Goldstein et al., 1997), speed of task performance, and perceptual motor skills (Whitcomb, 1990).

Work has been conducted in designing an interface that should be easy to use for people with dementia. Alm et al. (2003) developed an interface and a navigation system that could be used to help people with dementia communicate better with others, especially in situations where the disease had affected working memory and made conversation with others difficult. The system developed was a multimedia system with a touch screen. A touch screen was used because it is the easiest interaction technology for people with dementia (Alm et al., 2003). The system provided different themes that could be chosen as support for conversation. In the interface each theme was associated with a colour. When a theme was selected the background colour and colour of all buttons was changed to reflect the selected theme. The evaluation showed that people with dementia were encouraged and supported in setting the direction of the conversation (Alm et al., 2003). The system mentioned above has also been extended with the use of QuickTime VR (QTVR), which provides a 3D interactive environment. The aim was to give house-bound people with dementia the opportunity to experience environments and activities that they enjoy, for example, a walk in the garden or a visit to an art gallery (Gowans et al., 2004). Virtual reality environments have also been used in studies investigating the possibility to measure cognitive age-related decline and to assess age-related CNS (central nervous system) disorders such as Alzheimer's disease (McGee et al., 2000). Virtual reality environments for older adults have also been investigated as a tool to assess and improve visuo-spatial skills such as visual field-specific reaction time, depth perception, 3D field dependency (virtual rod and frame test), static and dynamic manual target tracking in 3D space, and spatial rotation (McGee, et al., 2000).

Work related to computers and technical devices have been conducted with the aim to assist people with age-related diseases in their everyday life. These achievements fall, to some extent, outside the scope of this thesis; however, some work related to this area will be described as an example of another area where computers and other technical devices could help older adults and improve quality of life. One such an effort is the Assisted Cognition project (Kautz, Fox, Etzioni, Borriello & Arnstein, 2002). This is a project that has been investigating the use of AI (Artificial Intelligence) systems to support and enhance independence and quality of life for people who suffer from Alzheimer's disease or similar cognitive disorders. The systems developed within the Assisted Cognition project have used ubiquitous computing[4] and AI to compensate for the decline in memory and problem-solving that people with Alzheimer's face. Two examples of systems developed within the Assisted Cognition project are the "Activity Compass" that reduces spatial disorientation, and the "Adaptive Prompter" that helps patients conduct everyday tasks, which consists of several steps (Kautz et al., 2002).

3.3.6. Mobile phones and design for older adults

Design considerations and recommendations for older adults and the use of small devices, such as mobile phones, is quite a new field. Many of the studies that have been conducted have investigated methods to acquire information about needs and preferences of older mobile phone users (for example, Mikkonen, Väyrynen, Ikonen & Heikkilä, 2002; Smith-Jackson, Nussbaum & Mooney, 2003). However, some design recommendations have been suggested, for example, easy operation without advanced functions, functions that are simple and easy to use, clearly marked keys, design consistency, and confirmation feedback when a function is completed (Smith-Jackson et al, 2003). Large keys with equal amount of space between them, reduces the demands on psycho-motor skills. Mobile phones with rubberized covers have been found to be easier to use because of the grip support (Smith-Jackson et al, 2003)

As mentioned, older adults have more difficulties in creating mental representations of the hierarchical menu structure that is used in many mobile phones. The awareness of the hierarchical structure has been suggested to be crucial to effectively use the mobile phone. Due to this, it will be important to make this navigation structure more transparent to the user (Ziefle & Bay, 2004). Navigation through complex functions and

[4] Ubiquitous computing compromises all the technology and systems/services that can be built into our everyday objects and environments, such as in our homes, cars, roads, lamps, etc.

complex menu structures is difficult for older users (Maguire & Osman, 2003); therefore, it has been suggested that the users should be able to customize the menus. If limited features or fewer functionalities are preferred, it should be possible to deactivate certain features in the menu (Smith-Jackson et al, 2003). Another suggestion that has been offered is designing a single-line menu structure that is not more than two levels in depth. This would reduce search times for older adults who are more likely to return to the top level when searching for a new task. However, if there is a need for much different content, menus not deeper than two levels will have too many options and be too wide. For these information environments on mobile devices, one further layer of main categories has been suggested. Buchanan et al. (2001) developed two systems called WebTwig and PowerBrowser. These systems provided tree-like representations of the information structure, where only the top level was visible in the beginning. When one node at the top level was selected, the tree expanded to show the sub-topics related to this node. Navigation in mobile Internet environments should be based on hierarchical information structures, something with which users already are familiar from use of mobile phones. Navigation can also become easier if text input is replaced with list selection, if vertical scrolling is avoided, and if long messages are replaced by action-oriented keywords. Finally, it is important that the information content is summarised and available with few keystrokes or text entries (Buchanan et al., 2001).

Important mobile services aimed at older users, are those applications that support social relations (Mikkonen et al., 2002; Morris, Lundell & Dishman 2004) and safety applications, such as emergency calls (Mikkonen et al., 2002). One example of addressing the safety need was the EU-funded project MORE (Mobile Rescue Phone Project). The aim with the project was to develop a mobile phone prototype that was easy to use for older adults and that provided both mobile phone functions and alarm functions. The prototype was a redesign based on an existing design of a mobile phone. The interface was developed to be easy to use. The device was easy to hold and use, with large keys that were placed with some space between one another. To address the safety needs, the phone developed in the project had an emergency button placed above the interface. The work in the MORE-project also aimed at creating efficient access to emergency services. Besides acting as a centre for emergency calls, the service centre provided additional service to the MORE users (Mayer, Edelmayer & Zagler, 2000; Mäki, Klause & Zagler, 1998).

In Japan, NTT DoCoMo was one of the first service providers to market a mobile device that was easy to use. The device was targeted towards users with little or no experience of mobile phones, and towards users with limitations in psycho-motor or cognitive skills. The RakuRaku-model offered, for example, a larger display, large adjustable characters and text, simplified instruction menus, and automatic read-aloud of menus (Scuka, 2003). With respect to vision limitations, other mobile phones with interfaces with large size fonts, unique high-legibility, and readability fonts have been developed for the Japanese market. For users with audio limitations, a mobile phone application has been developed that automatically displays Japanese hand-sign communication, converted from spoken or written input (Marcus, 2003).

Based on the dynamic diversity approach and on the ever-changing variability within the older adult, it could be beneficial for older users if the mobile phone could provide feedback about this variability. Data from sensors within the phone and cognitive tests embedded in the interaction could provide information about the individual's present state, and the devices could adapt to this state. For example people with dementia could be helped, if they were encouraged to conduct more cognitively demanding tasks during moments when they actually are able to accomplish these tasks (Morris, Lundell, Dishman & Needham, 2003).

Handheld electronic navigation and other location-sensitive aids often use systems such as GPS (Global Positioning System) to identify the users' location (Goodman & Gray, 2003). With this technology the user is localised with high precision and accuracy (Abascal & Civit, 2001). Based on the information about the user's location, information about how to reach a wanted destination is provided (Goodman & Gray, 2003). The GPS technology is being used to locate people for security and safety reasons as well. In case of an emergency, a user can be identified, localised, and assisted (Abascal & Civit, 2001; Goodman & Gray, 2003). Location-based devices and services are already in the market and they are likely to become more widespread in the future (Abascal & Civit, 2001). The older population may be a new large target group for location-based services and it has been reported that older adults have a positive attitude towards location-based services (Osman, Maguire & Tarkiainen, 2003). Other new location-based services, such as locating products in a shopping mall or assistance in travelling, are also gaining interest among older adults.

3.3.7. Trends in development and demands on future products

There is a large amount of possibilities to use ubiquitous computing with respect to older adults. Wireless systems that are using different devices and sensors could provide a more secure home environment. Mobile phones and other hand held devices could provide location-based services such as navigation help or providing information about different locations. Social isolation and social aspects related to ageing have become more in focus. This is an area where it could be beneficial to provide new services, which are targeted towards older adults. The development of methods for assessing different needs, preferences and requirements is a research area that is growing. There is increasing work being done towards actually understanding which services different groups of older adults would benefit from, and new methods are being developed with this aim.

3.3.7.1. Older adults and ubiquitous computing

As mentioned earlier, adaptive systems will have to adjust not only to differences among individuals, but also to the variability within each individual. To effectively monitor and interpret input data from devices and sensors within the household (or elsewhere), it is important to examine which input variables in different contexts, alone or in combination with others, will be relevant to use in determining different system behaviours. The input data must also be interpreted based upon the individual's behaviour and the variability within this behaviour. The superiority of human-human interaction has been pointed out to be able to capture large amounts of context information. A lot of information can be transferred in a short period time in human interaction. Human communication could provide situational context and information about the environment, such as background noise, and whether the individual is alone or in a group, or about the individual in terms of mood or whether he/she is busy or not (Tarkiainen, Osman & May, 2003).

It has been suggested that ubiquitous computing devices that are using positioning and sensors could be beneficial for older adults. The use of the information from sensors could contribute to making environments more safe, support daily routines, or enhance communication. However, there are several privacy concerns that must be addressed and the technology must take (data) security into consideration (Jorge, 2001). Further, the acceptance among the users is dependent on to what extent the users trust the systems, with respect to both secure data transmission and with respect to the people who are receiving it. Connected organizations, personnel who work in residences for older people, and/or call centres must be trusted and perceived to be reliable in terms of acting on the received information.

3.3.7.2. Services that enhance social interaction

One area that has been placed in focus, regarding the development of electronic services and the needs of older people, is the social isolation among many older adults. Services have begun to be developed that are focusing on the importance of facilitating social relations with friends and family, as well as enhancing the possibilities to maintain these relations. These services are important with respect to age-related cognitive decline or impairment, since many cognitively impaired older adults are facing difficulties related to the social interaction with other people. Morris et al. (2004) suggested an application that facilitated spontaneous joint activity. The system consisted of sensors that registered when a person was about to leave the home or when low activity was detected. In those situations, a companion could be notified that an opportunity to contact or join that person had arisen.

Older adults that are exposed to decline in cognitive functions often face difficulties in remembering names and faces. By providing different social memory aids, these difficulties could be reduced and the social interaction with other people could be made easier (Morris et al., 2004). Morris and colleagues suggested a social memory aid that provides the user with photographs of people they know. These photographs are connected to information and memory cues about the person and about the relation to him/her. When designing systems targeted towards certain aspects of age-related decline or impairments in specific cognitive functions (for example, difficulties in remembering names and faces), knowledge about how to design interfaces with respect to these specific age-related declines will be crucial.

The older population is increasing and many older adults are living in their homes for a longer period of time. One growing social problem is related to not being aware of a relative’s day-to-day activities. Technology addressing this issue has been designed. For example, Mynatt, Rowan, Jacobs and Craighill (2001) have suggested a concept that can increase the awareness between family members. The concept consists of a digital family portrait that provides visualisations of a family member’s daily life through a picture frame. Pictures of the family members are placed in those frames, and based on sensor information the frame is changing. The changes of the frame convey awareness about one family member’s daily activities to another family member who is living at a different location.

3.3.7.3. Methodological issues

To be able to develop new products and services that are found to be useful and meaningful, it is important to continuously investigate the new and/or changing needs among older adults and different groups of older adults. It is also important that new services and products contribute to increased wellbeing and increased independence among older adults. If services are not found to be meaningful to older users, the technology will not be used. User needs and motivation are important with respect to cognitive aspects of usage since these issues might affect the amount of cognitive effort a system is given by a user. Methods that capture the needs among older adults, with respect to new technology and new services, have been placed more in focus and there is an ongoing and increasing effort in finding successful methods to involve older people in the design process. One example of a method that has being developed, even if not specifically addressed at older adults, is a method named "Cultural Probes". With this method, a package of materials is presented to the participant as a gift. The material is designed to inspire the participants and can consist of postcards, a camera, and a notebook. The aim of this method is to encourage the participants to new ways of thinking and to share information about everyday behaviour, needs, and preferences (Gaver, Dunne & Pacenti 1999). Another example of how to approach the participants to have them involved in the design process, as described by Eisma, et al. (2003). The authors give suggestions about how to create a common ground between developers and older users. By explaining the design process and by providing hands-on experiences, the older adults can become more actively involved in the design process with communication between users and designers being improved (Eisma et al., 2003). To be able to capture the dynamic change over time, as well as the variability between and within individuals, a design approach that is designing for dynamic diversity has been suggested. This approach also suggests modifications to the user centred design process, where a more user sensitive inclusive design takes the variety between and within individuals into account (Gregor et al., 2002).

Based on the ever-changing needs between both individuals, within, and around the same individual, adaptive interfaces have been suggested. However, several practical and ethical issues have to be discussed and solved. Such questions as to what extent are people willing to give information about themselves, which information about a user can be or can not be used, and how should the large number of affecting variables be interpreted and used with respect to different individuals and in different contexts. In addition, interfaces that take the dynamic diversity into account and adapt to different users and to differences within one user, must be developed based on extensive work on how this adaptation should be accomplished with respect to different needs and preferences. Adapting and changing the information for the same individual from session to session may also create confusion (Höök, 1996). On the other hand, when the user controls this functionality, there is a risk that the system will be difficult to use, especially for older or less experienced users. Overall, the older population, in the future, will have more experience with technology and will have higher demands on the interfaces. Systems that do not adapt to the dynamic diversity that is in line with the users preferences, skills, and acceptance are less likely to be used. Finally, older adults are reluctant towards buying products that are specially designed and marketed towards them. Those devices can have a stigmatizing effect by marking the user as someone that needs special help (Hanson, 2001). On the other hand, if the devices contribute positively to the user's self-image, they will be more easily adopted and more frequent used (Hirsch et al., 2000).

To summarise, the variations among and within older users are larger than they are among younger users. Adaptation to different user needs has been pointed out to be especially important for older adults because of this variability. Much work has been conducted regarding interface design that takes the age-related cognitive decline into account. Several recommendations and guidelines exist with the aim to make web sites easier for older adults to use. Some applied work have also been conducted in terms of investigating if the guidelines are met by different web sites, or in terms of implementing applications with a particular focus on older users. Not only the design of the interfaces are important with respect to the age-related cognitive decline, different ways of structuring and presenting information and the type of task are also important factors affecting performance.

4. EMPIRICAL STUDIES

The overall purpose of the experiments reported in this dissertation was to investigate age-related decline when using different interfaces, information structures and tasks. Further, to investigate which aspects of the age-related cognitive decline that played the largest role. Two studies were conducted regarding the use of computer interfaces. In study 1, the information was presented with a hierarchical structure. In study 2, the information environment was presented in terms of a 3D-environment and an overview map. In study 3, age-related decline in the use of a small mobile phone display was investigated. The information in study 3 was, as in study 1, presented with a hierarchical structure. However the amount of space that can be used for presenting information in this environment is of course much smaller than in a computer interface; therefore, factors such as the overview and/or the usage become quite different.

4.1. Study environments, participants and tasks

Online grocery shopping was chosen as the domain for the two studies on the use of computers and computer interfaces (study 1 and study 2). This domain is particularly interesting with respect to older users, making it possible to order food from home and to get food delivered to the doorstep. This could be useful for older adults who sometimes have difficulties in both travelling to the store, as well as carrying the groceries home.

As mentioned, it is also important that older adults using computers can find relevant services on the Internet. Buying groceries on the Internet may be a service that many people can find the motivation to try and to use. Online food stores have several thousands products, and; therefore, are a challenge to users' navigational skills and management of large information spaces. At the time when the research started, online grocery shopping was also a lively, active field.

The third study investigated the use of a mobile phone and its small interface. The use of mobile phones has increased over the last few years and it has become possible to use the mobile phone for several other things far more than just making phone calls. From this perspective, older adults will have to manage these devices and services, in order to communicate with others in the same way as other groups in the society. The overall purpose of study 3 was to examine how older adults could manage to use and understand information presented in limited amount of space and to what extent they could use and benefit from mobile services other than making phone calls.

4.1.1 Participants

There are large differences among subgroups of older adults with respect to coming into contact with and in using new technology (Östlund, 1999) and there are large differences in computer experience between both younger and older adults and between different groups of older adults. The older participants in these experiments were recruited from SeniorNet clubs and from organisations for retired people. "The seniors in SeniorNet are not necessarily a representative sample of seniors" (Ito et al., 2001, p.16), since they "are notably literate and technically competent" (Ito et al., 2001, p.16). However, participants with some experience with computers and mobile phones were deliberately chosen to make the age differences in experience as small as possible.

The participants in the present studies were between 60 and 77 years of age. This age group of older adults was chosen with the aim to include participants that were old enough in order to actually measure age-related cognitive decline, yet they were healthy enough to measure decline solely related to normal ageing. Older adults over 80 years of age were also excluded from the experiments, because of the likelihood of differences being related to prior experience with technology. This difference might be larger for the oldest group of older adults who never used computers in their work life before they retired.

The purpose of the experiments was to study the use of interfaces and the decline in cognitive abilities in normal ageing; therefore, subjects in any stages of dementia could not participate. The participants' performance on the cognitive tests included in the experiments was examined with the intention to detect and exclude subjects with dementia. None of the participants in the studies scored so low that there where any reason to expect dementia. No test was explicitly conducted to exclude people with dementia, because the social situation related to the experimental session made it difficult to suggest tests scanning for dementia to the participants. They were expecting to visit a research institute for new technology where they were going to try new applications; not a place where they were going to be tested whether they had dementia or not. Further, only 5% of people in the particular age group, 60 years of age or more, have some kind of dementia (Ferri et al., 2005), thus the risk of including participants with dementia are low. Finally, it is unlikely that people with preclinical dementia are those who participate in SeniorNet activities. Preclinical dementias often withdraw from social activities when they start noticing that they might have an age-related disease such as dementia; therefore, it is unlikely that they would commit themselves to be a part of experiments where they have to take the initiative to participate.

4.1.2. Task environments

In all three studies the aim has been to use environments, interfaces and tasks that were existing services or close to real-life usage of the technology. The experiments were designed in this manner with the aim to achieve high ecological validity. In study 1, a commercial online grocery store was used, and the participants conducted tasks similar to real-life online shopping tasks. In study 2, the participants were presented with an interface that was developed for the purposes of the experiment. This interface included most of the functions that could be expected in an online grocery store. The tasks in study 2 were also designed to be perceived as close as possible to realistic online shopping tasks. In study 3, commercial, existing, mobile services were used. The tasks in the study were chosen based on functionalities and services that are quite commonly used. Overall, the studies were conducted in naturalistic environments; however, instructions about how to conduct the tasks had to be given to the participants in order to control the experiments and variables affecting the results.

4.2. Summary of the empirical studies

4.2.1. Study 1

"The effect of age-related cognitive differences, task complexity and prior Internet experience in the use of an online grocery shop"

As discussed in previous sections, the use of computers is affected by various age-related declines in abilities such as psycho-motor skills, perception, and cognition. Several studies show that older adults have less computer experience than younger adults (Dyck & Smither, 1994; Kubeck et al., 1999; Mead et al., 2000) and that older inexperienced users are more disadvantaged than younger inexperienced users (Mead et al., 2000). These age differences in prior experience may explain some of the differences between younger and older adults performance on computer-related tasks (Kelly & Charness, 1995). However, other factors seem to be important as well (Czaja & Sharit, 1997). One further factor that might affect the computer-related task performance differently for different age groups is task complexity. The performance of older adults is affected more than that of younger adults when task complexity is increased for both cognitive tasks in general (Gick et al., 1988; Salthouse, 1992) and for computer-related tasks (Kubeck et al., 1999).

4.2.1.1. Research questions and hypotheses

This study examined how age, Internet and computer experience, and task complexity were related to navigation and search in a hierarchical online grocery store. Impact on performance of spatial ability and working memory was also examined. The hypotheses for the study were that the differences in performance between experienced and less experienced would be larger for the older users, that there would be larger age-related differences with the complex tasks, and that older adults with no or little experience are those who will have most difficulties with the complex tasks. Furthermore, it was expected that measures of working memory should be related to time spent with the tasks. It was also expected that a relation between performance, age, and spatial ability, particularly with regard to spatial visualisation, would be found.

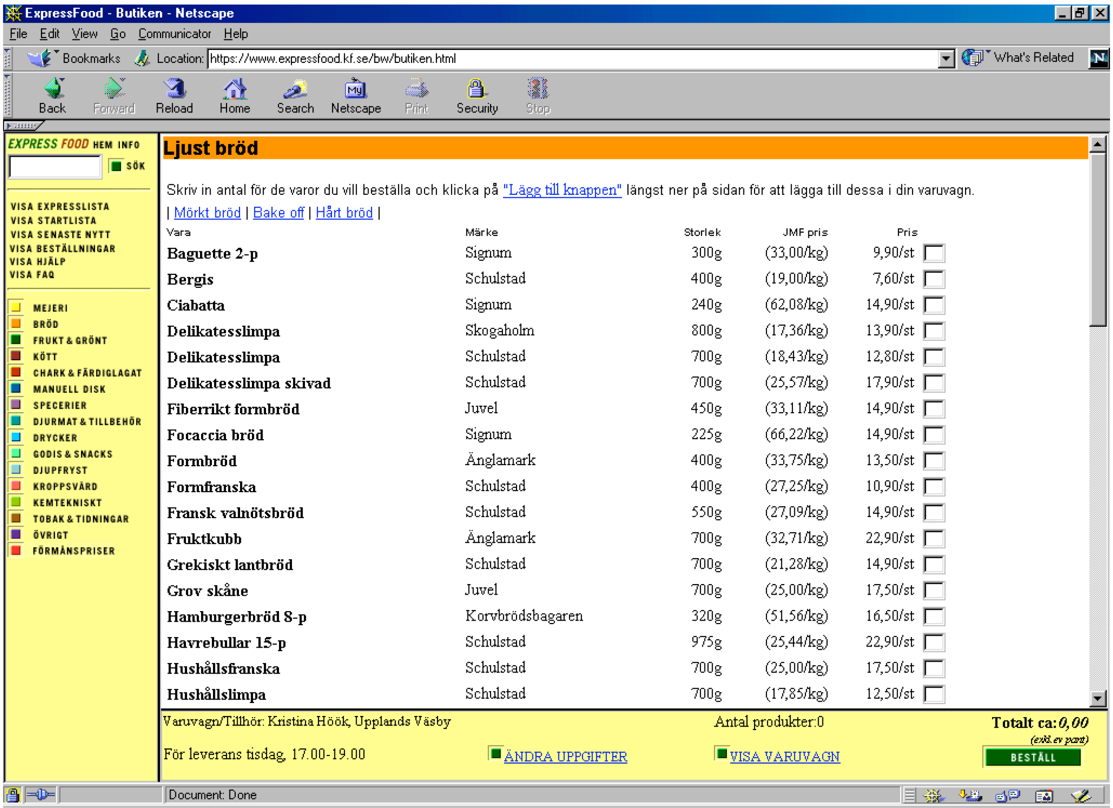
4.2.1.2. Method

In the present study, there were 48 participants, 24 younger adults (20-30 years, m=25.33) and 24 older adults (60-77 years, m=66.83). Half in each group were men and half were women.

All participants conducted one easy task and one more complex task within the online grocery store. The tasks consisted of two shopping lists composed by the experimental leader. One was an easy list with six everyday items, such as milk and bread. It was obvious where to find these items. The other list that was more of a weekly shopping list and consisted of ten items. These items were harder to find because they were less common products and it was not obvious to which category they belonged. Both the total time spent (including errors and items not found) and time spent only on items found were measured.

The online grocery shop used within the experiment was a commercial hypertext-based store. It was an online service that was present on the Internet at the time of the study; however, it was removed a couple of years later. The online shop was organised in a hierarchical fashion: on the top level, the users faced the main groupings of goods, such as dairy products, bread, and beverages. After choosing one of these categories, users either arrived at specific products or at subcategories. Finally, at the lowest level, the consumers could select what specific brand of the product they wanted and how many items and/or weight of the product they wanted to purchase (see figure 4).

Figure 4 Screen-shot of the online grocery shop used in the study



In a questionnaire, the participants were asked to state age, gender, educational level, and computer/Internet experience. Further, the participants were asked about how much time they thought that they had spent with the system, since underestimated time could indicate higher user enjoyment (Richmond, 1996). Finally, the participants conducted cognitive tests where they were tested on spatial rotation (Mental rotation; Shepard & Metzler, 1971), spatial visualisation (Paper folding – 'Plåtmodeller'; Psykologiförlaget, 1992), and working memory.

4.2.1.3. Results and conclusions

The results were in line with earlier studies (Kubeck et al., 1999; Mead et al., 2000), in that the older participants needed more time to complete the tasks. Both age groups spent more time to find the items in the complex task; however, the older participants spent more time than the younger participants with the complex task. Complex tasks place higher demands on cognitive resources than easy tasks and they also demand more self-initiated processing, which is more difficult for older adults than for younger adults (Craik, 1983). Performance of complex tasks also place greater demands on working memory (Salthouse, 1992), which declines with increased age (Gick et al., 1988; Salthouse, 1992) and has been described as an important mediating variable of age differences with respect to computer-related tasks (Czaja, 1996) and other cognitive tasks (Kirasic et al., 1996).

Results from regression analyses showed that, when the task was complex, there was an impact on performance from working memory. Spatial visualisation and age also had an impact on performance when the task was complex. On the other hand, when the task was easy, Internet experience had the strongest impact on performance. This may be explained by less demand on cognitive resources and a lager effect of familiarity with functions and navigation in a typical hierarchical Internet service.

Earlier studies found that older users with no or little computer experience have more difficulties than younger users with no or little experience (Kelly & Charness, 1995; Mead et al., 2000). The results from the present study (study 1) showed that the relation between age and computer experience was only present when the task was complex. The older participants with less computer experience needed more time to complete the complex tasks than the younger participants with less experience. Finally, according to Richmond (1996), underestimated time spent is a measurement of user enjoyment during task completion. The less experienced older participants, in the present study (study 1), underestimated the time they spent performing the tasks. Thus, even if it took a long time to solve the tasks, these older users did not experience it as such.

4.2.2. Study 2

"Age differences and the acquisition of spatial knowledge in a three-dimensional environment: evaluating the use of an overview map as a navigation aid"

Older adults might benefit from using a three dimensional (3D) environment for online grocery shopping in several ways. For older adults who have difficulties in visiting a real life grocery store, the 3D-environmnet can create opportunities to mediate experiences and impressions from visiting a real store. These environments are rich in terms of visual cues such as pictures and photographs, and the visually distinctive cues in a 3D-environment can also allow for processing of memory cues to a greater depth, which is beneficial for older adults, because it will facilitates free recall of objects located in space (Sharps & Gollin, 1988). In addition, the structure and layout from a real life store can be kept; therefore, it will be possible to navigate in a familiar environment where knowledge from visiting real life stores can be used. This could be especially helpful for older users since it facilitates encoding at a deeper level. For example, Craik (1972) suggested that familiar and meaningful stimuli are compatible with existing cognitive structures and will be processed to a deep level more rapidly. These stimuli will be better retained than less meaning full stimuli (Craik, 1972). Finally, a Virtual Reality (VR) or a 3D-environment can be efficient from a spatial awareness point of view. It will provide the user with the possibility to follow the complete path between different objects in the environment and thereby maintain the spatial awareness at a higher level (Bowman et al., 1998).

Older adults do not, to the same extent as younger adults, create configural knowledge (Lipman & Caplan, 1992). By providing the users with an overview map of the environment, the demands on creating this "mental model" might be reduced. However, some studies have demonstrated that older adults do not benefit as much from diagrams or model descriptions of space as younger adults (Caplan & Schooler, 1990; Lipman & Caplan, 1992), since they have more difficulties in translating 2D-information to 3D-information (Wilkniss et al., 1997). However, it has to be further investigated in which situations and in which electronic environments overview maps can serve as a navigation aid with respect to both younger and older users.

4.2.2.1. Research questions and hypotheses

This study examined age-related differences in the use of an electronic 3D-environment, and how the age differences were affected by the use of an overview map as a navigation aid. Besides task performance, the participants' acquisition of configural knowledge of the 3D-environment were measured and used to explore to what extent the results from 'real' world navigation would transfer to the problem of navigating an electronic environment. The impact of spatial ability and prior experience of computers and Internet was also examined, with respect to both performance measurements with and without the overview map and to measurements of configural knowledge.

An overall hypothesis for the present study (study 2) was that differences in learning and performing navigational tasks in the physical world are similar to learning and performing navigational tasks in the virtual world. Furthermore, the hypotheses for the study were that the older participants would need more time to solve the tasks and would be less likely to create configural knowledge. It was expected that the older participants would benefit more from an overview map as cognitive support than would younger participants. Finally, it was expected that spatial ability would have an impact on performance and men would perform better than women in solving the computer-related tasks since men perform better on spatial ability tasks (Linn & Petersen, 1985).

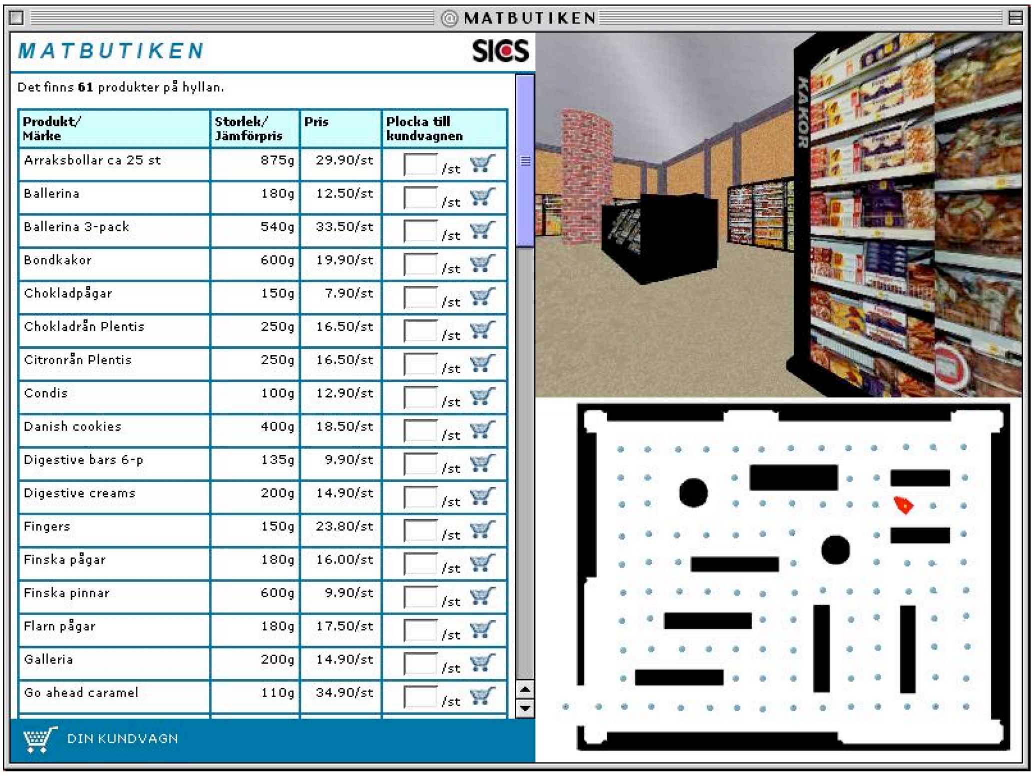
4.2.2.2. Method

In the present study, there were 48 participants, 24 younger adults (20-31 years, m=25.50) and 24 older adults (61-77 years, m=66.88). Half in each group were men and half were women.

All participants performed shopping tasks both with the 3D-interface alone, and with the 3D-interface together with an overview map. The participants were asked to perform in the 3D-environment by finding and selecting groceries in the store listed in two equivalent shopping lists, each with 6 items. The measurements used were time spent and number of interaction steps used. After each session (with and without overview map), the participants estimated where in the store they thought that they had found the grocery items. These measurements were gathered to assess acquisition of overview knowledge. The angle between the participants indicated position and the correct position was measured from a reference point. The reference point used was the entrance of the online shop. The distance between the participants' suggested position and the correct position were also measured.

The 3D-environment was an online grocery shop built with Strata Vision 3D and QTVR (Quick Time Virtual Reality). The objects in the environment were created with Strata Vision 3D and were covered with photos of food shelves as textures. The photos were taken in a physical grocery store. The spatial layout of the digital environment was also based on an existing physical store. The shelves in the online shop were clickable and connected to a database of products. The database search result consisted of all products and product categories that were represented on that specific shelf. The overview map of the shop had an arrow that indicated actual position and headed direction of the user. The overview map was fixed and did not move with the users actions or movements. The overview map was not clickable. The only way to move around in the store was through the actions in the 3D-representation (see figure 5).

Figure 5 The 3D-shop used in the study



In a questionnaire, the participants were asked to state age, gender, educational level, computer/Internet experience, and experience with 3D-applications. The participants were also asked to rate their overview knowledge of the environment and their sense of direction towards objects, both with and without the navigation aid. All participants performed two spatial ability tests, spatial visualisation (Paper folding – 'Plåtmodeller'; Psykologiförlaget, 1992) and mental rotation (Mental rotation; Shepard & Metzler, 1971).

4.2.2.3. Results and conclusions

The results showed that the older participants spent more time and needed more interaction steps to find the items than the younger participants. These results are in line with earlier findings on older adults and the use of computers (Kubeck et al., 1999; Mead et al., 2000; Sjölinder et al., 2003), where older adults need more time to solve different computer-related tasks and reach poorer final levels of performance. In the present study (study 2), age differences related to the use of the overview map were small or non-existing. It has been claimed that older adults do not benefit from using a model (Caplan & Schooler, 1990) and in the present study (study 2) the overview map did not reduce the age difference in performance. However, the overview map did not make the situation worse for the older participants and it provided a sense of control over the environment. Several of the older participants reported that they felt more comfortable with the overview map present and that it reduced the feeling of being lost.

Regarding impact of background variables on time spent and number of interaction steps used to navigate, age and Internet experience were related to performance with respect to time spent. The impact of experience on computer-related tasks is also in line with earlier studies showing that the effect of age on computer performance is reduced when the amount of experience is controlled (Kelly & Charness, 1995). Regarding the number of interaction steps used, only age was related to performance in the present study (study 2). The relatively larger impact of Internet experience on time spent might indicate that navigation is not greatly affected by experience. It is, rather, the time it takes to decide where to go and what do next that is affected by inexperience.

The results regarding the acquisition of configural knowledge showed that the older group performed less well. They made larger errors in pointing out where objects in the environment were located, and reported having less sense of direction towards the objects. These results are in line with results regarding navigation and use of configural knowledge in real environments where older adults are less inclined to create configural knowledge (Lipman & Caplan, 1992), make more direction judgement errors, and rate their sense of direction as poorer than younger adults (Aubrey & Dobbs, 1990). Regarding impact of background variables and spatial ability on the measurements of configural knowledge, age and computer experience had an impact in the conditions without the overview map present. On the other hand, Internet experience had the strongest impact on performance when the map was present. None of the spatial ability measurements had an impact on the acquisition of configural knowledge. Prior experience seemed to be more important, and one interpretation of this is that the prior experience affects the possibilities to learn the structure of the environment in a way where users with little experience have to focus their attention on the actual usage of the system instead of mentally creating an overview of the spatial relations within the environment.

4.2.3. Study 3

"Age-related cognitive decline and the use of mobile phones and mobile services"

The possibility to carry a mobile phone might increase quality of life for older adults in several ways. By bringing a mobile phone it becomes easier to call for help in emergency situations, which makes it possible to visit places that otherwise would have been avoided. Older adults who are using a mobile phone report a higher level of feeling safe in situations where they earlier felt unsafe (Brandt, 1996) and have also report a sense of having increased opportunities to live an independent life (Abascal & Civit, 2001).

Despite older adults' growing use of mobile phones, there are several aspects of the use of the mobile phones and mobile services that are difficult. Mobile phones have limitations in terms of small screens and multifunctional keypads that are limited and difficult to use (Ericsson, Chincholle & Goldstein, 2001). Information search in small interfaces is more difficult, less information can be presented at each time, and the user must scroll more in text sections and move around more in menu structures (Jones, et al., 1999). The limited amount of space in a small interface demands a more complex menu structure that is difficult to have an overview of and to navigate in. The complex menu structure and its many options can be especially hard for older users. Older adults who are using mobile phones also report that they feel that the menu structures are too deep (Tuomainen & Haapanen, 2003). Vision impairments are common among older adults (Jones et al., 1999) and the age-related decline in vision creates difficulties with reading small text in displays and interfaces (Bernard et al., 2001; Ishihara et al., 2001; Maguire & Osman, 2003). Older adults who are using mobile phones have reported difficulties with seeing the numbers and letters on the buttons (Maguire & Osman, 2003). With respect to the age-related decline in psycho-motor skills, the buttons are placed too close to one another and use of text message functionalities is more difficult for older users (Maguire & Osman, 2003).

4.2.3.1. Research questions and hypotheses

This study examined age-related differences in the use of a mobile phone and in the use of mobile services. It was further examined how the age-related differences affected performance of different tasks. The tasks in the present study (study 3) consisted both of tasks that were related to use of a mobile phone and of tasks that were related to the use of different mobile services through WAP[5]. Impact of perceptual speed, working memory, spatial ability, and prior experience was investigated regarding the different tasks. The hypotheses for the present study (study 3) were that the older participants would need more time and use a higher number of interaction steps to solve the tasks than younger participants. It was also expected that the age differences would be larger, with respect to time spent and number of interaction steps used, on search tasks where little information about the search domain was given. The older participants were further expected to experience larger difficulties in acquiring an overview of menu structure and content than the younger participants. Finally, it was expected that the older participants would experience more problems in finding and making use of buttons and seeing the content of the display.

[5] WAP, Wireless Application Protocol, is a protocol for making web pages accessible through mobile phones. It includes the possibility to send and receive e-mail, chat, and search for information.

4.2.3.2. Method
In the present study, there were 20 participants, 10 younger adults (22-26 years, m=23,40) and 10 older adults (60-72 years, m=63,80). Half in each group were men and half were women.

All participants performed tasks related to the use of the mobile phone functionalities and also WAP related tasks. The phone tasks and WAP tasks consisted of different kinds of subtasks. The phone tasks were divided into searching in menus versus using text-writing functions (e-mail), and the WAP tasks were divided into performing searches within a predefined search domain versus performing searches without instructions regarding where to conduct the searches. Half of the participants started with the free search tasks and the other half with the predefined search tasks.

The mobile phone used in the study was a Sony Ericsson T68i. The phone had a joystick for navigation in the menu structure. The main menu and its subcategories used icons to illustrate the content in each category. The subscription used was *Telia Mobile OnLine*. This subscription gave access to the WAP portal *MyDOF* with approximately 100 mobile services. The portal consisted of access to services through navigation among subcategories based on different topics such as news, TV, games, and location-based services (see figure 6).

Figure 6 Sony Ericsson T68i, main menu

In a questionnaire, the participants answered questions regarding background variables such as age, gender and prior experience. Questions on mobile phones experience as well as Internet experience were asked. Further, the questionnaire consisted of questions regarding subjective opinions about different aspects of the use of mobile phones about both mobile phones in general and about the particular mobile phone used in the study. At the end of the session, the participants performed four cognitive tests. Perceptual speed was measured by *digit symbol*, and working memory for symbols were assessed by *digit symbol modified* (Wechsler, 1986). Further, verbal working memory was assessed by *Daneman and Carpenters test for verbal working memory with shared aspects* (Daneman & Carpenter, 1980), and finally spatial visualisation was measured by a test called *paper folding* (Psykologiförlaget, 1992).

4.2.3.3. Results and conclusions

The results showed that the older participants needed more time, used a higher number of interaction steps, and had a slower interaction speed to solve the tasks related to the functionality of the mobile phone. In general, the participants needed more time, used a higher number of interaction steps, and had a slower interaction speed with the task that demanded written responses. The older participants especially needed more time for the text-writing task. For this task it seemed like the age-related difference was related to difficulties in finding and using the correct letter. The older participants had difficulties with finding the correct button and with finding the correct letter among those connected to a specific button. The result regarding the use of text-writing functions was in line with earlier findings where using the text message functionality was reported to be more difficult for older users (Maguire & Osman, 2003). In the present study (study 3), there was an impact of age and experience with mobile phones and the Internet for both the menu/change option task and the task requiring text to be written. However, in the menu/change option tasks, there was also an impact of verbal working memory on performance. There was a larger impact of verbal working memory on performance than of working memory for symbols. This can be explained by the demands on being able to remember the textual content in the menus.

The older participants also needed more time, used a higher number of interaction steps, and had a slower interaction speed on tasks that were related to the use of different services (WAP tasks). In general, the participants spent more time, used a higher number of interaction steps, and had a slower interaction speed on the WAP tasks that included instructions regarding where to search for information. However, with respect to interaction speed, age-related differences were less prominent when information about where to find the information was present. This might indicate that the older users did not benefit from the possibilities of finding the information at several different places (as in the free search task) to the same extent as younger users. Instead, the search situation becomes more complex, thereby putting a higher cognitive load on older adults (Gick et al., 1988, Salthouse, 1992). The assumption that the free search situation was more difficult for the older users is also supported by the fact that older adults are less inclined to sort out task relevant information (Morris & Venkatesh, 2000). With respect to impact of background variables, Internet experience affected the use of WAP services in both search situations. This is most likely due to the similarities between the WAP services interaction scheme and the normal structure and interaction with web pages on the Internet. Perceptual speed also had an impact on performance in both search situations. This was not unexpected, because of the amount of information to be processed, choices to be made, and the various ways of selecting information pieces. This selection of task relevant information is more difficult for older adults (Morris & Venkatesh, 2000). For the predefined search task, verbal working memory had an impact on performance as well. For the free search task, age and working memory for symbols also had an impact on performance. The impact on performance of age in the free search task may indicate that the older participants benefited less from being free to perform the search in a domain that they had selected themselves, because this situation consisted of a more complex search environment with more choices to be made.

5. DISCUSSION AND CONCLUSIONS

The aim of this thesis has been to investigate age-related cognitive differences in the use of different interfaces (computer interface and mobile phone interface), different information structures (hierarchical and three dimensional), and different tasks (different levels of complexity). The differences between these environments with respect to age-related cognitive decline will be discussed below, as well as the use of environmental support and navigation aids. Design implications for the different environments will also be discussed, based on the experiments conducted as a part of this thesis and on previous research. Finally, thoughts will be given on experimental design for this area in general and on the experiments conducted for this thesis.

5.1. Age-related differences, background variables and different interfaces

Within the three experiments that were conducted for the work with this thesis, the most pronounced age differences where found in the use of the 3D-environment, study 2 (see table 4). Several factors are likely to contribute to the differences in performance between the interfaces. First, the 3D-interface and environment were entirely new to many of the older participants; on the other hand, there were similarities to playing computer games, something from which several of the younger participants had experience. The 3D-environment was also the most demanding information structure, regarding ageing, cognition, and demands on acquiring and using spatial knowledge. Finally, the interaction was conducted by moving through the environment by clicking in certain areas in front of or beside the actual location. This way of interaction might have been especially difficult for the older participants due to both less experience and age-related decline in psycho-motor skills.

Table 4 Age-related differences in the present studies

	Time spent and cognitive measurements affecting performance	Number of interaction steps and cognitive measurements affecting performance
Hierarchical interface	F(1,40)=16.53 Easy task: *Internet experience* Complex task: *Age, spatial visualization,* working memory	
3D-interface	F(1,44)=75.42 *Age, Internet experience*	F(1,44)=27.17 *Age*
Mobile pone interface	F(1,16)=26.51 Easy task: perceptual speed Complex task: *age*	F(1,16)=16.86 Easy task: *Internet experience*, working memory Complex task: (perceptual speed, working memory)

With respect to background variables, impact of age, Internet experience, and spatial visualization was analyzed in all three experiments of this thesis. Two of the experiments were conducted using a hierarchical information structure, one presented on a computer interface (study 1) and the other presented on a small mobile phone interface (study 3). Both of these experiments included conditions with an easy task and a complex task. Regardless of the size of the interface, no impact of age was found when conducting an easy task within any of the hierarchical information structures. However, prior experience seemed to have a larger impact on performance on the easy tasks within the hierarchical information structures in both the experiment with the computer interface and in the experiment with the mobile phone interface. On the other hand, when the tasks were complex there was no impact of prior experience; instead, age and cognitive abilities had a larger impact on performance (see table 4). The larger effect of prior experience on easy computer-related tasks and the larger impact of cognitive abilities on more complex computer-related tasks were also found by Freudenthal (2001) where menu selection tasks on the top-level in a hierarchical information structure showed a larger impact of prior experience than the menu selection tasks further down in the hierarchy.

As mentioned, the most pronounced age-related differences were found in study 2, using a 3D-interface. Within this experiment, only cognitive measurements, which related to different aspects of spatial ability, were assessed, because one of the aims with study 2 was to investigate ageing and spatial ability in the use of an environment that was mostly "spatial" in its character and assumed to place high demands on different aspects of spatial ability. However, none of the measured aspects of spatial ability (spatial visualization and mental rotation) were found to have an impact of performance within this environment. These results could be explained by the absence of similarity between the tasks conducted in the spatial tests and the tasks conducted within the environment. It might be hypothesized that the navigation within the 3D-environment actually placed demands on different aspects of spatial ability; however, these processes were not captured within the cognitive tests used in the experiment.

The spatial visualization aspect of spatial ability has been found to be related to the use of computers and interfaces (Kelly & Charness, 1995). Within the experiments conducted for this thesis, the only impact that was found of spatial visualization was on the computer-related complex task within the hierarchical information structure (study 1). This could be explained in terms of the hierarchical information structure being more obvious and pronounced within the large computer interface with respect to both the possibility to visualize the information structure and previous experience of using hierarchical information structures presented on a computer screen. Regarding performance on the complex task using a mobile phone interface with a hierarchical information structure, only age was found to have an impact on performance. This result might also suggest that the participants' mental models of the mobile phone's hierarchical information structure were less applicable, especially for the older participants, because older adults have been found to have difficulties in creating a mental model of the navigation structure within mobile phones (Ziefle & Bay, 2004).

In several studies spatial ability has been shown to be sensitive to gender differences (Linn & Petersen, 1985), where men perform better in spatial and navigational tasks. Spatial ability has been shown to be associated with performance on computer-related tasks and navigation in virtual environments (Benyon & Murray, 1993; Bowman et al., 1998; Dahlbäck et al., 1996; Vicente & Williges, 1988) and it might be hypothesised that performance on these tasks would be affected by gender differences as well. Previous research has also found gender-related differences in studies of virtual environments (Billen, 2001; Czerwinski, Tan, & Robertson, 2002; Waller, Hunt & Knapp, 1998), and based on these findings and on the gender-related differences in spatial ability it is shown to be well-considered to include gender as a variable in analyses of computer-related tasks and navigation. However, in the studies included in the present thesis no gender-related differences were found with respect to the performance measurements. In studies 1 and 3, both having hierarchical information structures, this could be explained by the fact that the environments and the structure of the information were to some extent verbal/semantic. The understanding of the structure of the environment was based on an understanding of text, categories and submenus, and with respect to verbal abilities women have an advantage compared to men (Herlitz, Nilsson, & Bäckman, 1997). Even though the women might have been disadvantaged with respect to the spatial aspects of navigation in these environments, their performance might have been equal to the performance of men due to the impact of verbal understanding and use. In study 2, the 3D-environmnet, gender differences were expected due to the spatial nature of the environment. However, the final level of navigation within this environment also consisted of quite large amounts of text. Therefore, it is likely that the lack of gender differences in performance could also be explained in terms of advantages in spatial ability (men) versus verbal/semantic abilities (women) cancelled each other out. Furthermore, it might also be the case that women are more familiar with the grocery shopping domain, and that this experience contributed to the lack of gender differences. In studies 2 and 3 gender differences were found with respect to questionnaire items: in study 2, the older women reported more difficulties in learning to move around within the 3D-environment, and in study 3 the older women reported it to be more difficult than the other groups to see the content of the mobile phone display. However, several factors such as gender differences in reporting, and use of strategies might affect how the information is perceived and attended to.

Impact of working memory on time spent was analyzed with respect to both the easy task and to the complex task using the hierarchical interfaces (computer interface, study 1 and mobile phone interface, study 3). Regarding time spent, working memory was found to have an impact on performance only for the complex task conducted with the computer interface. Studies of cognitive tasks in general have also shown that complex cognitive tasks place greater demands on working memory (Salthouse, 1992). Working memory is also affected by increased age (Gick et al., 1988; Salthouse, 1992) and Freudenthal (2001) found that age-related differences in performance increase when a computer-related task becomes more complex, consisting of more steps to be taken. The larger age-related difference for more complex computer-related tasks was suggested to be associated with increased demands on working memory, and with age-related differences in working memory. The decline in working memory also affects the ability to use and integrate new information with information that has been acquired earlier (Sharit & Czaja, 1994). This integration of information is likely to be a more frequent component in performance of complex tasks than in performance of easy tasks.

In study 3 of the present thesis, which investigated the use of a mobile phone interface, both time spent and number of interaction steps was measured. Effects and impact of age seemed to be more pronounced when using the measurement time spent. This finding was not surprisingly, due to the well-established age differences in processing speed. The results in study 3 further showed that the only cognitive measurement, which had an impact of time spent, was perceptual speed. The age differences in performance measured by time spent on computer-related tasks have been investigated in other studies as well. For example, Czaja et al. (1998) showed older people are disadvantaged in performance of computer-related tasks where speed of responding is emphasized. With respect to number of interaction steps in study 3, prior experience and working memory were also found to have an impact on performance. This is not unexpected, because the navigation efficiency in a small mobile phone interface is likely to be dependent on previous experience of the navigation structure and of the capacity to remember how to move within the information structure.

To summarise, the age-related decline does not only manifest itself differently in different interfaces or information structures, it also manifests itself differently from task to task and whether or not the task is complex. Different tasks place a variety of demands on cognitive processes, as well as using a variety of cognitive resources.

5.2. Different information structures and older users

The studies that have been conducted for this thesis has investigated age-related cognitive decline in the use of different interfaces and information structures. Below, the results from these studies are discussed in relation to previous work within the area.

5.2.1. Hierarchical information structures

Many of the tasks that a user is conducting within a hierarchical information structure consist of searching for a particular piece of information or an answer to a question. The navigation consists of moving through different levels within the information structure, beginning at the top-level, moving further down the hierarchy through sub-categories and finally reaching the desired answer or information somewhere in the information structure. In several of the studies that have been conducted on navigation in these environments, the tasks have been to search for different pieces of information. However, impact of age and cognitive abilities has not been measured in most of the conducted work.

5.2.1.1. Associations with cognitive abilities

Among those studies that have measured navigation, age and impact of cognitive abilities in hierarchical information structures, age (Freudenthal, 2001; Sjölinder et al., 2003), reasoning speed or processing speed (Freudenthal, 2001; Westerman, 1995), movement speed (Freudenthal, 2001), working memory (Sjölinder et al., 2003), and measurements of spatial ability (Freudenthal, 2001; Sjölinder et al., 2003) have been found to predict performance. Processing speed such as movement speed and reasoning speed (Freudenthal, 2001) and prior experience (Sjölinder et al., 2003) shows a larger impact on easy tasks or simple selection tasks. On the other hand, the impact of age and cognitive measures such as working memory (Sjölinder et al., 2003), spatial measures (Freudenthal, 2001; Sjölinder et al., 2003), and memory (Freudenthal, 2001) have been found to predict performance on more complex tasks or tasks that involve navigation in lover levels within the menu structure (see table 5). These findings are supported by the study conducted by Westerman et al. (1995), where spatial visualisation and spatial memory only interacted with age in a condition with embedded contextual information, which might have created a more complex information environment. On the other hand, by providing more contextual information the amount of environmental support is increased, which can contribute to facilitating the task and thereby provide a less complex information environment. This could be especially beneficial for older adults, who are more disadvantaged in complex environments and rely more on environmental support. To what extent a task is, or is perceived to be, complex or not is likely to be based on each individual's presuppositions and previous knowledge. There needs to be a balance between individual needs and the increased risk of demands on different cognitive processes in order to attain the extent to which systems should provide contextual information to facilitate task performance.

Table 5 Impact of age and cognitive abilities on hierarchical interfaces

Interface	Task	Time/speed	Author(s)
With contextual information	Menu selection	Age*spatial visualisation Age*spatial memory	Westerman et al., 1995
Without contextual information	Menu selection	Age	Westerman et al., 1995
Linear vs. hierarchical vs. network-based information structures	Information retrieval, finding answers to specific questions	Best performance for all groups with a linear information structure Age-related differences in processing speed was found to be an important factor	Westerman et al., 1995
Hierarchical, small menu structure	Information retrieval, finding answers to specific questions, navigation in menu structures, depth vs. breadth	Age, movement speed, reasoning speed, spatial ability First selection: movement speed, reasoning speed. Later selections: memory, spatial measures	Freudenthal, 2001
Hierarchical	Easy task: finding common grocery items	Internet experience	Sjölinder et al., 2003
Hierarchical	Complex task: finding grocery items with ambiguous categorization	Age, spatial visualisation, working memory	Sjölinder et al., 2003

5.2.1.2. Implications for design of hierarchical interfaces

It has been suggested that interfaces, which are complex or place high demands on working memory and spatial abilities, will be a disadvantage for older users. On the other hand, interfaces that consist of semantic content or provide rich contextual information place less demand on working memory and therefore it is likely that these interfaces are less affected by the age-related decline. Age differences increase when the tasks become more complex and the perceived degree of complexity is dependent on the individual's abilities and knowledge about the domain. If a system should provide contextual information or environmental support to reduce task complexity, it is important that the support is given at an appropriate level, for the individual.

One way of reducing the demands on cognitive abilities such as spatial ability and working memory is to use menus that consist of a single level hierarchy (Westerman, 1995). However, this may lead to interfaces with many menu options, creating a complex environment that in turn also become a disadvantage for older users. It is important that the navigation structure is balanced between depth and breadth, so that the items in each menu and number of steps that have to be taken to complete a task are balanced (Westerman, 1995). Due to the increasing demands on working memory and spatial ability with deep menus, deep menu structures are less suited for older users (Freudenthal, 2001). Older users are also more inclined to return to the top level to regain orientation. If the menu structures are deep, older users will have a greater disadvantage, because there will be more movement within the hierarchy (Meyer et al., 1997).

In study 1 of this thesis, the hierarchical online grocery shop, the older participants experienced difficulties in finding items that could belong to several main categories. Many of the items in the online shop were also categorized in another group, than most people are familiar with from a real life grocery store. In those situations, the older participants were less inclined to try to find the items in alternative places. Instead, they continued their search in the wrong subcategory. This behaviour might be explained by the age-related decline in conducting self-initiated processing (Craik, 1983) or by the cognitive slowing that reduces the "dynamic" capacity of working memory (the amount and quality of information simultaneously available in working memory) (Salthouse, 1996; as described by Anderson & Craik, 2000). With respect to interface design of online grocery stores and similar environments, it becomes important to provide design solutions that make both the information space less complex and provide assistance in finding new ways to search for wanted items or pieces of information. For example, when the user has visited the same place within the information space several times after one another, a question of what he/she is seeking could be asked and a hint about using a search function could be given.

One further way to reduce the complexity of the information space could be to divide the space it into smaller subparts. By designing these subparts distinctly from one another in both appearance and characteristics, the information space will appear less complex. Another example to reduce the complexity of an online shopping task is to provide the grocery store with a weekly shopping list, which contains the most common items bought by the same customer in previous purchases. Then, the task becomes divided into checking the "basic" weekly shopping list and searching or navigating for special items bought occasionally. Not only does this create smaller subtasks, it also reduces the amount of navigation and search for the same items repeatedly. This design solution could be applied to other online shopping domains and other information spaces by dividing the tasks into one part consisting of what the user does on a regular basis and into another, which consists of actions that are varying between sessions.

5.2.2. 3D-interfaces and virtual reality environments

Virtual reality or 3D-environments are spatial to their nature and it is likely that spatial ability will be associated with performance in these environments. Both in the study that was conducted for this thesis (study 2) and previous research have investigated the impact of different aspects of spatial cognition on performance in these environments. Their similarities with physical environments also make it intersenting to investigate similiarities in navigation and if a map can provide navigation support similair to map usage in the physical world.

5.2.2.1. Aassociations with cognitive abilities

Study 2 of this thesis (Sjölinder, Höök, Nilsson & Andersson, 2005), which was conducted in a 3D-environment, associated age and prior experience with performance. In the study conducted by Moffat et al. (2001), performance on a VR navigation task was positively correlated with measures of mental rotation, verbal memory, and visual memory. As mentioned, mental rotation was associated with performance in the study by Moffat et al. (2001), but not in the tasks conducted in study 2 of this thesis (see table 6).

Table 6 Impact of age and cognitive abilities on 3D-interfaces or VE

Interface	Task	Time/speed	Interaction steps	Author(s)
3D-interface		Age, Internet experience	Age	Sjölinder et al, 2005
Virtual environment	Navigating a series of interconnected hallways (where some of them were leading to dead ends)	The older participants spent more time, traversed a longer distance, and made more spatial memory errors Performance was positively correlated with mental rotation, verbal memory and visual memory. The age effects were still present after adjustments for computer experience and joystick visuo-motor control		Moffat et al., 2001

One explanation to the different findings may be that the tasks were quite different from one another. The tasks, in the study by Moffat et al., were pure navigation tasks; therefore, they might have been more closely related to spatial knowledge and orientation. The tasks in study 2 of this thesis mainly focused on finding items within the environment. In this study, no explicit instructions where given related to navigation performance. Another possible explanation may be the difficulties with the interaction technique the participants faced in study 2 (Sjölinder et al., 2005). It might be hypothesized that much of that performance was influenced by psycho-motor skills and by prior experience, as shown in the analysis. The impact of prior experience might have played a relatively large role, because both the interaction technique and the environment for navigation were new to many of the participants, in particular to the older participants. Finally, the interfaces and the tasks in the two compared studies were also very different. For example, in study 2 of this thesis (Sjölinder et al., 2005), the written information might have contributed to different demands related to the use of different cognitive process.

5.2.2.2. Implications for design of 3D-interfaces

In the 3D-study (study 2) conducted as a part of this thesis, the older participants faced more difficulties than the younger participants in regaining orientation when they lost track of where they were. The importance of maintaining spatial awareness was demonstrated by Bowman et al. (1998). This might be especially important to older adults because of the age-related decline in creating configural knowledge (Lipman & Caplan, 1992). When having insufficient overview knowledge it might become more difficult to regain orientation, because the present location cannot be placed in relation to other objects within the environment. To design features in 3D-environments that provide help in regaining orientation could therefore be beneficial for older adults. One example of providing such an aid is to create a design that has obvious differences between subparts of the environment. This would make it easier to regain orientation (and reduce complexity) because the environment that the user is lost within will be smaller. The user could then know in which subpart of the environment he or she is. Help in situations where the user is disoriented could provide a going back functionality. By "walking backwards", the user could arrive in an earlier location where he/she had orientation. One further example of supporting navigation is to provide a clickable overview map. By navigating through a clickable overview map, the user would be able to choose a place within the environment, click on the map, and regain orientation at a familiar location the user has chosen him/herself. The interaction technique is also important for older users who might have difficulties with fine motor movements. Using a mouse (as in study 2 of the present thesis) has the advantage of using a familiar input device; however, clicking on areas in front of the position to mark where to go is demanding on psycho-motor skills. It is easy to make mistakes, jump in an unintended direction, and become disoriented.

As previously mentioned, the impact of spatial ability might be related to different designs or design features, the environmental support provided, and the tasks that are conducted. For example, in situations where the environment is very spatial in its nature and at the same time provides verbal or contextual information, the impact of spatial ability is less pronounced (Westerman, 1995). This suggests that additional verbal and contextual information might be important and that relevant verbal and contextual cues or features should be taken into consideration when designing interfaces.

One further important design issue, especially in the design of 3D or VR environments, is the enjoyment of using the application. A 3D online food store might be a useful tool for older users who need help in ordering groceries, and simultaneously be a pleasure to use. In situations where older adults are unable to visit a physical store, a more visually oriented electronic environment can add value to the experience. Pictures or a 3D-environment could add to the real life shopping experience by providing an environment that is rich in terms of visual cues enhancing the user experience. It is likely that much of the benefit of using a 3D-environment lies within these values of experiences, rather than being an environment where tasks can be conducted efficiently. Performance measurements must also be viewed with respect to such values, in some cases users do not care whether it takes longer to find each individual item on the shopping list since other values might be more important, such as having a good time or being able to "walk around" in the store. In these situations, when having a good time is the main aim, time spent might not be important; however, users might care about being lost or not even finding certain items. To help them overcome the various obstacles of learning how to use the system, the system must address other needs than efficiency of use. Similar to how shopping in a physical store can be a positive, social and visually attractive experience, shopping in a virtual environment also must include these aspects.

5.2.2.3. Navigation aids in 3D and virtual environments

Older adults have difficulties with keeping track of where they are; therefore, they need support in orientation (Meyer et al., 1997). One way to support navigation and to provide orientation help is to add an overview map to the 3D-environment (Darken & Sibert, 1993). Several studies have been conducted regarding effects related to having an overview map as a navigation aid, but there is no conclusive evidence as to the extent an overview map supports the user. Previous studies have shown very mixed results, ranging from increased performance to decreased performance. For example Darken and Sibert (1996) found that the use of an overview map, in way-finding tasks, increases navigation performance in a virtual environment. Ruddle, Payne and Jones (1999) found that performance on information searches increase when an overview map is provided. Furthermore, Han and Kwahk (1995) showed that performance was faster and more accurate when an overview map was provided in a menu navigation task. On the other hand, it has been found that the use of an overview map is not necessary for the learning of an environment (Johns, 2003). In some situations, it has been found that the use of an overview map can have negative effects on the learning of the environment (Satalich, 1986; reported in Johns 2003). Lipman and Caplan (1992) demonstrated that older adults do not benefit as much from diagrams or model descriptions of space as younger users. In tasks related to transformation of 2D-information to 3D-information, Wilkniss et al., (1997) found that older adults were disadvantaged, because they had difficulties going from the 2D-information provided by a map to aid in understanding the 3D-environment. These findings might have an impact on how older adults benefit from an overview map. On the other hand, older adults do not create configural knowledge of the space to the same extent as younger. In situations where there is a need to gain an overview understanding of the environment, a navigation aid with an overview map might help the understanding of the environment. In these situations, the overview map might serve as an environmental support, which provides configural knowledge in situations were users have difficulties in constructing this knowledge mentally.

Although the performance related aspects of the use of overview maps have been discussed, it seems as if overview maps improve how the interface is perceived.

Overview maps seem to contribute to a more positive experience (Johns, 2003), and supports older users create a feeling of the location of objects within the environment (Sjölinder et al., 2005). A model such as an overview map is of help to both older and younger users in terms of supporting a better and more correct understanding of the layout of the information space. However, the use of overview maps also place higher demands on cognitive resources, which might slow down the users. If it is of importance that users learn the layout of the space, then the trade-off between acquiring configural knowledge versus efficiency, might favour of implementing a map in the interface. On the other hand, if the layout is unimportant and the users do not need to return to the space or find their way back, then the map should not be included. There is a need to balance the goal of making users feel less lost and more secure, as they do when an overview map is provided, against the goal of efficiency. In many cases, older users do not care if it takes longer to find each individual item on the shopping list; however, they do care about being disoriented or not finding particular items.

Ruddle, Payne and Jones (1997) found that participants develop 'cognitive maps' in a virtual environment, which are similar to the maps derived from exploration of the real world (Moffat et al., 2001). Study 2 of this thesis also indicates that navigation in virtual space is similar to navigation in physical space. When designing navigation aids it should therefore be possible to pick up some of the lessons learnt from navigation and use of maps in the physical world. For example, the map might be aligned with the position of the viewer (Aubrey et al., 1994). However, this needs to be carefully crafted so that it does not increase the demands on internalising the model conveyed by the map. Whenever the target group includes older users, this should also be done in ways that take the age-related cognitive decline into account. Requirements on ability to construct configural knowledge and ability to integrate one's own configural models with those presented by the system must be placed in focus. The overview map should also be made optional in the interface so that users who dislike or have difficulties in using map-like representations are not bound to use these features.

Other ways of providing navigation support in 3D or virtual environments have been investigated. Chewar and McCrickard (2002) found that the navigation aids with the most positive effect on different performance measurements were an image of an arrow pointing in the headed direction, a text list of forthcoming directions to chose, and an auditory description of the next step to take. Neither an aid in terms of a full map with a solution path, nor a partial map were found to facilitate navigation performance (Chewar & McCrickard, 2002). However, one explanation to the lack of facilitation from the use of overview maps might be the joint demands on the same processes in working memory. When both the environment, for example, a 3D-environment, and the navigation aid (overview map) place high demands on the visuo-spatial processes of working memory, the cognitive demands might become too high. On the other hand, when the navigation aid is placing demands on verbal processes in working memory, the processing is likely to be less demanding (Baddeley 1996a; Baddeley 1996b; Tardieu & Gyselinck, 2003).

One further way to facilitate navigation in virtual environments can be by providing landmarks, as those used when navigating a real world environment. By placing landmarks in a sequence, paths and routes through an environment can be created.

When artificial landmarks are added in virtual environments, it is important that they are easy to distinguish from objects that represent data. The landmarks should be distinctive in terms of size, colour, shape and location, because large, colourful, and freestanding landmarks are better remembered than others. Landmarks should also be designed to consist of concrete objects rather than abstract ones (Vinson, 1999).

When providing a map with landmarks, it is important that the users are familiar with the used landmarks, and also that the landmarks are familiar to users across user groups. To meet the preferences of different user groups, the interface design could provide different sets of landmarks that allow the users to select a set of landmarks (Schafer, Bowman & Carroll, 2002). Different sets of landmarks might be especially beneficial for older users, because of the wide variation in experience, perception, and cognition within this user group (Goodman & Gray, 2003). It has also been found that the landmarks older adults chose or create are different from younger adults. Older adults are less effective in selecting landmarks (Kirasic et al., 1992) and their acquisition of landmarks is based on personal knowledge, personal evaluative statements, and non-spatial associations (Evans et al., 1984; Lipman, 1991; Lipman & Caplan, 1992). Therefore, it could also be beneficial for older users to use personalisation of landmarks, where the cues provided are adapted to the individual user (Goodman & Gray, 2003).

5.2.3. Small interfaces

The use of small devices and interfaces place other demands on the users than when interacting with computers. The fact that everything is smaller could make it especially difficult for older adults. It is also likely that the cognitive load increases due to lack of overview and difficulties related to the limited amount of space for presenting information.

5.2.3.1. Associations with cognitive abilities

In study 3 of this thesis, participants conducted searches on a mobile phone display, both with and without contextual cues provided. In the condition with contextual information, perceptual speed had an impact of performance with respect to time spent. In the condition without contextual information, age impacted performance measured by time spent (see table 7). It could therefore be especially beneficial for older adults to be provided with environmental support, since impact of age is less pronounced when environmental support (in terms of guidance where to conduct information searches) is provided (Sjölinder, Nilsson, Bergqvist & Höök, 2006).

Table 7 Impact of age and cognitive abilities on the use of small interfaces

Interface	Task	Time/speed	Interaction steps	Author(s)
Mobile pone interface	Predefined search (environmental support provided)	Perceptual speed	Internet experience, working memory	Sjölinder et al., 2006
Mobile pone interface	Free search (more complex search environment)	Age	Internet experience, perceptual speed, working memory	Sjölinder et al., 2006

Regarding navigation efficiency, Internet experience and working memory also had an impact on performance. This was not unexpected because the information structure in these environments are similar to the structure of web sites, and navigation places high demands on working memory in order to remember the correct buttons to press to reach the wanted functionality.

The use of small devices and small displays place high demands on several functions, which commonly are affected by the age-related decline in vision and psycho-motor skills. The decline in vision makes it more difficult to see the text on the buttons, and the selected line in the menu. In study 3 of this thesis it was found that older participants experienced more difficulties in using the buttons on the mobile phone. The older participants were more likely to press incorrect buttons, not press the buttons hard enough, or press them too many times than the younger participants. Repeated button-pressing by the older participants lead to increased disorientation because they moved further away in the hierarchy (Sjölinder et al, 2006).

In study 3 of this thesis, the older participants were more affected by poor feedback in the connection between pressing a button and a result on the display. The older participants seemed to have difficulties in understanding if the result was because of their own actions or not. The age differences in performance seemed to also be related to the lack of understanding symbols and menu structure. The older participants reported greater difficulties in understanding the icons in the main menu (the only menu that consisted of icons) and they experienced difficulties in acquiring an overview of all the options and functionalities, which existed in the menu structure. Furthermore, familiarity and understanding of the mobile phone interface environment, its metaphors, and its menu options seemed to be a problem. The older participants reported that they were able to see the icons; however, they continued press the wrong icon, an indication of difficulties in knowing the meaning of different icons. The same phenomenon revealed itself in menu selection. Although the older adults where able to read the text in the menus, they choose the wrong function, suggesting difficulties in understanding which functionality was connected to a particular menu option. These difficulties could be partially explained by the findings, suggesting that older adults do not create the same mental model of a mobile phone menu structure as younger users (Ziefle & Bay, 2004)

5.2.3.2. Implications for design of small interfaces

Vision impairments are common among older adults; therefore, design recommendations concerning the display suggest that it should be as large as possible. However, there are also possibilities to increase the font size or make it easier to distinguish contrasts. If there is a large amount of information to be displayed, for example a web site, the site needs to be adjusted to fit the smaller display. This will be especially important if the font size has been made larger, because a reduction in the amount of information on the interface will occur making it more difficult to gain an overview of the information structure. To reduce the information content, interfaces could be more adaptive to different user needs: such as creating an option that provides the opportunity to switch off less used functionality. The ways that mobile phones allow the user to customize the interface and the menus today are much too difficult and much too rough.

The use of mobile phones buttons, which have different functionality depending on the text presented in the display, may be more troublesome for older users who seem to be more inclined to think that one button always has the same functionality or produce the same outcome. Therefore, it is important that the connection between a button and the function it currently represents is made clear and explicit. It is also important that appropriate feedback is provided when the user had pressed a button, since older users are more insecure to whether pressing a button has lead to a system change. Navigation aid can help when the user is disoriented and would be beneficial for older adults, because the decline of psycho-motor skills may lead to unintentional clicks, which in turn causes confusion and disorientation. The dynamic diversity, which has been discussed in terms of interfaces adapting to different user needs. One solution to the diversity both between individuals and within individuals regarding mobile phone interfaces could be to use a personalised navigation technique (Smyth & Cotter, 2002). With this technique, the structure of the portal adapts to meet the needs and preferences of different users.

5.3. Experimental design and study tasks

Experimental design of user studies often has to be balanced between providing a naturalistic environment versus being able to conduct controlled experiments. Several considerations and choices has to be made regarding which aspects that should be included in the experimental setting; therefore, methods to deal with these issues are needed.

5.3.1. User studies, evaluations and different tasks

A number of contextual variables are present when a task is conducted in a real world setting. All of these variables cannot be included in an experimental design (Czaja & Sharit, 2003) or be measured in a reliable way. This leads to a number of uncontrolled variables that affect the results even if they do not reveal themselves in the laboratory setting. For example, in complex real world tasks, individuals use different strategies to deal with complex task demands (Mead et al., 1999). In many real-life work tasks, older adults are able to use their expertise and/or contextual support to compensate for the age-related decline (Czaja & Sharit, 2003). When investigating the use of interfaces from different perspectives there is a great advantage of using real-life interfaces with all functionality included, because the similarity with real-life situations leads to achieving high ecological validity (Czaja & Sharit, 2003). However, as pointed out by Czaja and Sharit (2003), it is important that ecologically valid research builds upon a theoretical framework and contributes to advancing this framework.

Within the work conducted for this thesis, the aim was to present the users with real-life environments and tasks, as well as using environments and experimental designs that provided the opportunity to investigate age-related differences in the use of the interfaces. In study 1, a commercial existing online grocery shop was used (Sjölinder et al., 2003). However, to some extent there was a lack of similarity with a real-life task in this study. Participants were given the instruction to not use the search function. This instruction was necessary to be able to measure the navigation through the environment.

If the participants had been given the opportunity to use the search function instead of navigating through the hierarchical structure, then the aim with the experiment could have been jeopardised.

In study 2, the 3D-interface study, the participants were presented with an interface that was developed for the experimental purposes. This interface included most of the functions that could be expected in an online grocery store, but similar to study 1, without search function. Another feature, which was excluded in the 3D-interface, was the possibility to navigate through clicking on the overview map. This design decision was also made in order to reduce the risk of participants avoiding navigating the intended environment. However, the main consideration in the experiments was to use as realistic environments and tasks as possible. The overall aim with the experiments was to investigate ageing and cognition in the use of different interfaces and information structures. It was also considered to be important to conduct the experiments in real task environments. Little work has been conducted within the area and with real-life environments, and it is important to not exclude experiential factors such as motivation and enjoyment. Furthermore, many people, including older adults, have experience with computers and interfaces. By presenting the participants with a system lacking many important features, to which they are normally accustomed, there is an increased risk of annoying the users and reducing the motivation to conduct the tasks as intended. When investigating cognitive aspects, it is also likely that cognitive processes involved in solving the tasks are different in a situation where just one part of the system or the interface is used within the experimental setting. In the work conducted for the present thesis, it was considered to be more important to provide the participants with meaningful real-life tasks in environments that were as complete as possible, despite the presence of uncontrolled variables.

In order to use realistic environments and tasks in the experiments, and at the same time control and measure different aspects affecting the interaction, Czaja & Sharit (2003) suggested a method combining task analysis, interviews, and observations. By developing scenarios for the experimental sessions and by simulating databases and information, a real-life experimental setting can be achieved. This experimental setting consists of a simulation of a work activity, as well as technologies and resources that are needed to perform the task (Czaja & Sharit, 2003).

In solving many real world problems, performance on experimental tasks is insufficient. However, some of the measurements used within a laboratory setting may contribute to knowledge of the sources of individual differences in performance (Czaja & Sharit, 2003). The use of different performance measurements should also be placed in relationship to the activity the users are conducting. For example, short time and few interaction steps could in some situations be desirable. However, it does not matter if the task takes a short time to solve, if the users dislike the system, and discontinue use. In many real-life situations, spending time or performing a high number of interaction steps might indicate an interest in exploring the environment rather than needing time to solve the tasks or being disoriented. Therefore, performance measurements become worth little without additional qualitative results and/or knowledge about the users' intentions and needs. There are several measurements that can be used to provide additional information, besides time spent and errors. For example performance measurements reflecting preference, workload, confusion, or quality of performance may also be useful (Czaja & Sharit, 2003). Finally, task differences may affect the results of different studies to a great extent. There is a need for more research investigating the differences between tasks, regarding ageing and cognition. As pointed out by Fisk and Rogers: "There is a crucial need for research programs aimed at clarifying how age-related changes in function affect older adults' ability to interact with technology successfully. To fulfil this need, researchers need to sample task environments, much as they sample participant populations" (Fisk & Rogers, 2002, p. 110).

5.3.2. Conclusions about the design of the conducted experiments

The main results from the experiments conducted for this thesis are in line with previous research regarding age-related decline in performance with respect to time spent and the impact on performance of age-sensitive cognitive abilities, such as processing speed and working memory. The methods and measurements used captured these age-related differences in the electronic environments that were investigated.

The experiments were designed and conducted with the aim to achieve high ecological validity. However, the experiments could have been more similar to one another to provide more possibilities in comparing variables and results between the experiments. For example, if a large number of cognitive tests, and the same cognitive tests had been used in all three experiments, more analyses related to the impact of cognitive abilities could have been made. Each session in the experiments continued for several hours; both practical and ethical considerations limited the available time for a session; therefore, it was necessary to make choices on which cognitive test to include. Further, the interfaces and the navigation tasks could have been more similar between the experiments in order to improve comparisons with respect to navigation in different information structures. However, this reduced the ecological validity because some of the tasks were unnatural for that particular interface or information structure.

Other quantitative measurements could have been used, such as measuring different kinds of errors and/or number of times the participants returned to the main level. In the conducted experiments alternative quantitative measurements were tested; however, they were tested in a more explorative manner for future purposes. Some of the measurements were found to be useful and others not. In study 2 of this thesis (the 3D-study) different aspects of measuring configural knowledge were used successfully and reported. On the other hand, more difficult measurements were different ways of assessing the use of landmarks within the 3D-environment. Several measurements related to the perception of the usage and the interfaces could have been included. However, all experiments included personal inventories or interviews. Observational data from the sessions was also gathered with the intention of future work on interface design.

5.4. Summary and general conclusions

Within the three experiments for the present thesis, the most pronounced age differences where found in the use of the 3D-environment (study 2). Impact of age, Internet experience, and spatial visualization were analyzed in all three experiments. Two of the experiments were conducted using hierarchical information structures, one presented on a computer screen (study 1) and the other presented on a small mobile phone interface (study 3). Both experiments included conditions with an easy task and a more complex task. Regardless of screen size, no impact of age was found when the participants conducted an easy task within any of the hierarchical information structures. However, prior experience had a larger impact on performance of the easy tasks within both these hierarchical information structures. On the other hand, when the tasks were complex, there was no impact of prior experience; however, age and cognitive abilities had a larger impact on performance.

Impact of working memory on time spent was analyzed both with respect to the easy task and to the complex task, as well as hierarchical interfaces presented on both a small screen and on a large screen. Working memory was found to have an impact on performance, measured by time spent, only for the complex task within the computer interface (study 1). However, in the experiment that was investigating navigation in a small mobile phone display (study 3), navigation efficiency was also measured. With this measurement, working memory had an impact on performance with respect to both the easy task and the complex task. With the 3D-environmnet (study 2), age-related effects and impact of age also seemed to be more pronounced for the measurement time spent than for the measurement navigation efficiency. This was not unexpected since the well-established age-related differences in processing speed could explain age differences in tasks and measurements that place a focus on speed of performance.

In the 3D-interface experiment (study 2), only cognitive measurements, which related to different aspects of spatial ability, were assessed. None of the measured aspects of spatial ability (spatial visualization and mental rotation) were found to be associated with performance within this environment. These results could be explained by the absence of similarity between the tasks conducted in the spatial tests and the tasks conducted within the environment. Especially the spatial visualization aspect of spatial ability has been found to be related to the use of computers and interfaces (Kelly & Charness, 1995). Within the experiments conducted for this thesis, the only impact on performance that was found with respect to spatial visualization was for complex task performance within the hierarchical information structure presented on a computer screen (study 1).

5.4.1. Design considerations

The age-related difference in solving easy and complex tasks was found in study 1 and study 3 of the present thesis. With respect to the easy tasks, prior experience was found to have an impact on performance in these studies. For those tasks, an interface design that provides help to novices could reduce the difference in time spent. On the other hand, more complex tasks demand design efforts that reduce the cognitive load, and thereby contribute to improve performance. This might be especially important for older users, because of their difficulties in conducting complex tasks. However, this brings up the question, "to whom and in which situations the tasks are complex or simple?" Some examples which arose from the work for this thesis constitute complex tasks within this area. These tasks could, for example, consist of menu navigation with several levels (Freudenthal, 2001), hierarchical navigation tasks where the categorization is not obvious and interpretable in differing ways by individuals from different user groups (Sjölinder et al., 2003), and search tasks with little information given about the search space. However, numerous variables might affect performance, such as impact of background variables, and whether a task is perceived to be complex or not. Work needs to be conducted regarding the type of cognitive support needed in different situations and for different tasks.

Contextual environmental support may be beneficial, especially for older users. It could contribute to a complex task becoming less complex during circumstances where it provides relevant support, in an appropriate manner for a particular individual. It will be necessary to find which contextual information is needed, for whom and when. "Designing for dynamic diversity", suggests adaptation based on the variability among and within individuals. The variables that are going to determine this adaptation has to be investigated with the aim to reduce the cognitive load as much as possible. If systems should efficiently adapt, it is important to understand different user goals. Based on these user goals, relevant input information from the context and the system could be used by the system. Interpretation of different performance measurements should be placed in relationship to the activity the users are conducting. Short time and few interaction steps could in some situations be desirable; however, users may also have other intentions where time spent is not important.

Time spent and number of interaction steps are relevant measurements, because they might tell us something about the efficiency in performing certain tasks. However, these performance measurements are worth little without knowledge about the attitudes users have towards the system and which activities they would like to perform. It is important to have an understanding of what the users expect to achieve with the system; whether they would like to conduct tasks as quickly as possible, explore the environment, or entertainment. This consideration might be especially important when designing for older adults, because the age-related decline in processing speed may contribute to misleading information about to what extent an interface design has been successful or not. The intentions users have with a system also affects important aspects in the interface and how adaptivity, adjustments, and help should be designed. For example, exploration might demand other kinds of navigation help than information search. Another intention with usage can be to visit places otherwise difficult to visit because of decline in different functionalities. For example, in the case of a 3D or VR shopping environment, older users with physical limitations have the opportunity to have a sense of presence in an online grocery store or in a shopping mall. They can "walk around" among the items and purchase item themselves instead of being dependent upon someone else. These values could be very important and time spent might be of very little importance in these situations. However, when designing interfaces for these purposes, as shown in study 2 of this thesis, it is important to use a manageable interaction technique despite of decline in psycho-motor skills. Another important design feature suggested by the work of the present thesis is to provide navigation help, which contributes to the ease of regaining orientation in situations where orientation is lost. In study 2, the older users were found to have more difficulties in regaining orientation, which was one aspect that contributed to the age differences in performance. This is an important design consideration, because having difficulties in regaining orientation also affects other aspects of how the usage is perceived. The feeling of being lost makes the entire usage confusing and less enjoyable.

It has been suggested that verbal contextual cues and/or environmental cues could be especially beneficial for individuals with low spatial ability and for older users who conduct complex tasks on computers or mobile phones. Older adults have also more difficulties in acquiring overview knowledge, which contributes to difficulties in knowing where certain pieces of information are located with respect to other pieces of information. Providing environmental support might be especially important when designing interfaces for small devices such as mobile phones, because Ziefle & Bay (2004) found that older adults have more difficulties in creating a mental model of the information structure. When the interface is small and less information can be presented at the time, the difficulties in creating mental models or overview knowledge might be even larger than when more information can be presented. In study 3 of this thesis (the mobile phone study), older users benefited when contextual cues were provided for a mobile phone display search. One challenge regarding the design of small displays will be to provide additional contextual information within an already limited amount of space. However, this support could make navigation easier, which justifies its presence on the screen. By providing environmental support, cues will be given that can narrow the search area or the possible information space to search. This leads to a smaller information space, which in turn might be especially beneficial for older adults who have more difficulties than younger adults when the amount of information is large. Finally, it was shown in study 3 of this thesis, proper feedback was very important for the older users. They often did not understand the link between pressing a button and a system action, which lead to further clicks resulting in disorientation. Therefore, it is important that the link between button and the present function of it is made clear and explicit, especially for older users. Finally, interaction would be improved for older adults if buttons were designed in a manner that reduces the number of involuntary double clicks and the number of involuntary clicks on the wrong buttons.

5.5. Future directions

The world population is on the rise, as well as the older population (Mynatt et al., 2001). Today, older adults also have less computer experience than younger adults (Kubeck et al., 1999; Dyck & Smither, 1994; Mead et al., 2000. However, this difference between the age groups will disappear in the near future. Many of the older adults who still working have come in contact with computers and are likely to continue to use computers in retirement (Morrell, 2001). The population born between 1945 and 1954 is a large age group that soon will retire. This age group is familiar with technology. Their demands on new technology will be high and it will be necessary to provide different technical solutions in order to provide the opportunity to continue working after the age of 65. Technology is also going to be used to a greater extent in the future with the aim to make it possible for older adults to live at home for as long as possible (Jegers, 2001). The older population will also become a more powerful consumer group. They will be a larger target group and they will be able to use the technology for a longer period of time since they will live longer. They will become more experienced in using new technical devices, and will place high demands on the technology, with respect to both functionalities and accessibility. Even though older adults will be more experienced in using technology than older adults today, the cognitive and physical limitations will remain, which will affect older adults' use of computer technology. There are several issues related to the age-related cognitive decline that will affect older adults use of different technical devices and services.

5.5.1. Age-related cognitive decline and different contexts of usage

There is a large diversity both among older adults (Birren & Schroots, 2001) and within the same individual. This variability place high demands on the design of future interfaces and services. Computer companies have begun to recognise the need to include features addressing impairments in vision, hearing, and mobility (Hendrix, 2000). Work has been conducted in writing design recommendations in order to make web sites easier to use for older adults; however, there remains work to be done within the area. It is important that applied research regarding interface design for older adults is driven by some approach based on psychological theory. In many situations when the design guidelines lack theoretical framework they become too general and difficult to apply. To avoid this, controlled experiments need to be conducted and explanations given that describe design solutions that are best during different circumstances (Mead et al, 1999).

It has been suggested that interfaces should adapt to different tasks, needs, and contexts both around and within the user. These different situations are most likely to be affected differently by ageing and cognitive decline. To be able to design interfaces that are easy to use, it will be important to investigate which usage situations that place high demands on cognitive resources, and also which cognitive abilities that affect performance most for different tasks and in different situations.

The intentions of each user in how the system or a service is to be used, for example, exploring versus searching, is also likely to affect the relavance of different background variables. To provide the interfaces and navigation help that meet the needs of older users with different intentions of usage, further research is needed. One further interesting aspect related to this issue is how the effect of the cognitive decline is perceived in different situations and which measurements of "performance" that are relevant in the different situations.

Within this thesis, the impact of easy tasks versus complex tasks has been discussed; however, the definition of what constitutes an easy task versus a complex task needs to be further investigated. Older adults benefit from environmental support to a greater extent than younger adults; however, research needs to be conducted regarding when, where, and how it should be presented in different situations and contexts.

Another interesting area, which is not the focus of the present thesis, is how strategies used in the physical world could compensate for age-related decline and be enhanced and used in the design of interfaces. By enhancing the use of these compensatory strategies within the design, the interfaces would also be more intuitive to use.

5.5.2. New devices and older users

With respect to limitations in psycho-motor skills and the use of small mobile devices, the design of the keyboard and of buttons is important. Further investigations are needed to examine how the age-related decline in motor skills and motor speed affects the usage of keyboards on small devices. Limitations in psycho-motor skills and memory make it difficult to enter text in mobile phone displays. This is an issue that needs to be addressed if older adults are to use services such as SMS, in the same manner as younger adults do. If older adults are to benefit from larger phones with larger buttons and displays, it is important that the devices and services contribute positively to the users' identity. It is important for older adults, to the same extent as for other user groups, that mobile phones are easy to carry around and that they convey information about the user, expressed by, for example, the mobile phone's style, shape, and colour. Therefore, devices and the services should not be developed especially for older adults; instead they should be easy to use for older adults as well.

Ubiquitous computing can enhance social interaction, and everyday objects such as hearing aids, watches, or refrigerator doors, all of which can be used as interaction devices. When the possibilities to interact with the technology will be all around us, it will become easier for older adults to maintain the social interaction with their communities (Morris et al., 2004). Other everyday devices, such as jewellery or buttons on clothes, have also begun to serve as computing interfaces with different functionalities. This will be a very different interaction than the one experienced with computers or mobile phone interfaces. New demands will be placed on the users with respect to both experience and age-related cognitive decline. Several new aspects of the use of ubiquitous devices, regarding ageing and cognition, will have to be investigated in order to design these devices and interfaces so that they are easy to use for both younger and older adults.

Interfaces that adapt to different contexts and user situations need much input: Input that sometimes could be difficult to gather. One important research issue is the context parameters needed to be gathered to provide important information to the system and to what extent these differ between different user groups. It is most likely that other or additional information must be gathered in the case of older adults, because they might be more or less affected by different environmental factors due to the age-related decline in different functions. With respect to mobile services, human operators can gather information about different contextual factors very quickly (Tarkiainen et al., 2003). Further research could provide information about situations, tasks, and services where human-to-human interaction could be beneficial for older adults and serve as a part of the interaction with the technology.

Finally, the development of different methods to gather information about older peoples' needs in terms of different devices and services is evolving. Several qualitative methods have begun to be used and developed for this target group. The use of devices and services in conducting different tasks has been placed into focus. Conducting controlled experiments that focus on interface design and age-related decline in cognition is important. There is also a need to place a larger focus on developing methods for dealing with the uncontrolled environment of an interface, with many possible options, and interactions that are affected by a variety of contextual and psychological factors.

To be able to capture the different needs among older users of technology, it will be important to investigate issues related to wanted and needed services, as well as how to design environments for different tasks and situations that take age-related cognitive decline into account. Individuals within the same group, both younger and older, differ in many ways. The decline in cognition and motor skills sets off at different times for different individuals. However, the age-related decline does, at some point, affect the ability to use technology; therefore, both age-related decline and the variability within individuals have to be taken into consideration in the design of interfaces.

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