Successful Cognitive Aging:

The use of computers and the Internet to support autonomy in later life

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Contents

Chapter 1

Introduction

Life expectancy has increased tremendously in recent decades. For instance, average life expectancy of women in the Netherlands was 72.7 years in 1950 compared with 81.1 years in 2004. For men, these expectancies were 70.4 and 76.4 respectively (CBS, 2005a). Together with the fact that the proportion of individuals aged 65 and older is also growing rapidly, from 7.7% in 1950 to 13.8% in 2004 in the Netherlands (CBS, 2005b), finding ways to improve the quality of life for older adults has become an increasingly important aim of gerontological research. More specifically, as was suggested by Rowe and Kahn (1997), research should aim at identifying strategies to promote 'successful aging'.

According to Rowe and Kahn, individuals who age successfully have a low probability of disease and of disease-related disability, have a high functional level (both physical and cognitive) and are actively engaged in interpersonal relations and productive activity. The number of studies that have focused on successful cognitive aging is still quite scarce. Nevertheless, there is some evidence suggesting positive effects of interventions aimed at promoting cognitive functioning in older adults (e.g. Ball et al., 2002; Schaie, Willis, Hertzog, & Schulenberg, 1987; Valentijn et al., 2005). What is still largely unexplored, though, is the possibility of interventions aimed not only at the promotion of the cognitive functional level in older adults, but also focusing on a second domain of successful aging: active engagement with life.

The focus of the present study was to increase knowledge about how successful cognitive aging can be accomplished and to explore the efficacy of a new intervention strategy to stimulate successful aging. This was done in the first place from the perspective of increasing cognitive reserve, or the ability to compensate for (age-related) brain damage or disease (e.g. Alexander et al., 1997; Stern, 2002). Secondly, the focus was on stimulating individuals to actively engage with life, which Rowe and Kahn also identified as one of the three primary dimensions of a successful aging trajectory. In the remaining sections of this chapter some background information of the present research will be discussed, including autonomy of aging individuals and the role of computer technology. This chapter ends with a brief overview of the aims and outline of the present thesis.

Autonomy in later life

A concept that is related to successful aging is autonomy. One of the major goals of older adults these days in the context of quality of life is to maintain an independent lifestyle (Rogers & Fisk, 2000; Willis, 1996). To remain autonomous in later life, older adults need to be capable of performing everyday routines, such as grocery shopping, personal hygiene and social contacts. Unfortunately, many of these everyday activities may become complicated as a result of age-related changes. For instance, many older adults become restricted in their mobility or experience other physical limitations related to their activities of daily living. Besides these physical restrictions, normal aging is accompanied by the decline of many elementary cognitive abilities, such as memory, speed of information processing and attention (see for example Craik & Salthouse, 2000). Also, for many older individuals, the frequency of contacting family and friends decreases (Due, Holstein, Lund, Modvig, & Avlund, 1999). A very important recent development in this context is the fact that more and more everyday tasks involve some degree of computer technology. As a result, the ability to deal with computers and computer-related applications is becoming increasingly important to autonomous everyday functioning.

Older adults and computer technology

Older adults are at a disadvantage in dealing with computer technology. Many individuals aged 65 or older have not learned to use computers at school or in the work place. Moreover, in the Netherlands only 23% of individuals aged 65 and older use computers, compared with 95% and 70% in individuals aged 25 to 44, and 45 to 64 respectively (CBS, 2005c). As a result of this, older adults experience more problems when they are faced with computer technology than younger adults do (Charness, Bosman, Kelley, & Mottram, 1996; Czaja & Sharit, 1993; Kelley & Charness, 1995). Consequently, older adults experience more problems with everyday activities that are more or less computer-based and therefore their ability to maintain autonomous functioning may be jeopardised.

While on the one hand the need to be able to use computers and technology to perform everyday activities is posing problems for older adults, on the other hand older adults could profit enormously from (computer) technological innovations. Many technologies and products may help older adults with some of their age-related problems and thereby assist them in maintaining their autonomy. For instance, applications of telemedicine enable communication with health care providers from home, hand-held computers can support individuals suffering from forgetfulness by providing reminders, and warning systems in the home may be used to monitor the health and safety of older adults without interfering with their daily life routines.

One of the computer-related developments that hold great promise to help older adults to deal with age-related changes and to increase their quality of life is the Internet. For instance, the Internet facilitates many of the everyday activities older adults may be restricted in doing, such as banking and shopping. Also, the Internet provides people with access to many sources of information. This may be practical information, such as public transportation timetables and opening hours, and also information that can be used for entertainment, such as book reviews, online courses and games. Besides the facilitation of everyday routines, the Internet also provides a way to maintain and improve social interaction and communication. Services such as e-mail, instant messaging and newsgroups offer new opportunities to maintain existing relationships and also to meet new people. Finally, as older adults have little experience with using computers and therefore also with using Internet facilities, learning such a new skill may require quite some cognitive effort from them. Moreover, cognitive abilities known to decline with age, such as memory, speed of information processing and selective attention, are involved in many computer and

Internet-related activities. Therefore, by encouraging older adults to use computers and the Internet, their cognitive abilities and their engagement in interpersonal relations and productive activity, two of the three dimensions of successful aging, may be stimulated.

Objectives and outline of this thesis

The research described in this thesis aimed at studying the impact of acquiring computer skills and of using a personal computer and Internet facilities on several aspects of autonomy in later life. The most important aspects of autonomy under investigation were cognitive ability, and wellbeing and quality of life. In order to achieve this objective, an intervention study was performed to investigate the impact of computer and Internet use on five separate domains: cognitive functioning, wellbeing and quality of life, the use of everyday technology, computer anxiety, and upper limb complaints, or functional limitations. The data from this study were also used to study the relationship between cognitive functions and the ability to use everyday technology. Two related research questions could not be addressed within the framework of the intervention study. Therefore, two more dedicated studies were conducted to explore predictors of computer use and the relationship between computer use and cognitive functioning in the general population (using data from the Maastricht Aging Study) and to investigate age differences in preferences of computer users with regard to design features of web interfaces.

This thesis starts with an explanation of the background and rationale of the intervention study and a concise review of relevant literature (Chapter 2). In this chapter, an explanation is given of why it is hypothesized that this intervention will have an effect on the cognitive functioning of older adults. The design and methods of the intervention study are outlined in the third chapter. Chapter 4 concentrates on the question of whether older adults who have been using computer and Internet facilities for twelve months show changes in cognitive performance compared with age peers who have not been using a computer. Chapter 5 addresses the same question with respect to several measures of wellbeing, quality of life and autonomous functioning. In the next chapter (Chapter 6) this thesis departs from the intervention study for a short while to focus on the role of cognitive functions in the efficiency of dealing with everyday technological tasks and also on the frequency and difficulty with which older adults perform these tasks. Chapter 7 uses the same measures to answer the question of whether older adults who have recently acquired computer skills will profit from these skills when using everyday technologies.

The following two chapters focus on two computer-related aspects that might have serious implications for the autonomy of older adults. Chapter 8 studies the question whether using a personal computer and the Internet for a one-year period will bring about changes in the level of computer anxiety participants experience, because computer anxiety may prevent individuals from using a computer or computer-related technology. Chapter 9 discusses the effect of this intervention on the development of upper limb complaints in older novice computer users, which is a possible negative side effect of computer use. Chapters 10 and 11 review data from populations other than those used in the intervention study. The tenth chapter looks at the relationship between computer and Internet use and changes in cognitive functioning in the Maastricht Aging Study (MAAS) in order to test the main hypothesis of this thesis in a large population sample over a longer period of time. The final chapter on experimental data (Chapter 11) focuses on the comparability between user preferences and general design guidelines for web-based interfaces from an aging perspective. A study is reported that aimed at finding age-related differences with respect to user preferences for web design and at the implications of these differences for design guidelines. Finally, in Chapter 12 the findings presented in this thesis will be discussed on a more general level in the concluding remarks. Here, both practical and theoretical implications of these findings are discussed.

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Chapter 2

Increasing cognitive reserve to attenuate age-related cognitive decline: The use of Internet as intervention tool

Submitted for publication
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Abstract

Individual differences in cognitive aging trajectories can be explained in terms of reserve capacity, which may serve as a buffer against age-related loss of brain function. The concept of cognitive reserve can explain why specific individual characteristics, such as education or participation in intellectually challenging activities, seem to protect against age-related cognitive decline. In addition, evidence suggests that cognitive reserve can be increased by stimulating the use of cognitive abilities, especially in older adults, which may slow the process of cognitive aging. A multifactorial training program that targets multiple cognitive abilities simultaneously may be an approach to counteract functional loss due to aging. In this chapter, we argue that learning to use a personal computer and the Internet may be such an intervention, because it requires many of the cognitive skills essential to everyday functioning. Moreover, information technology skills may increase the autonomy of older people in later life.

Many cognitive functions decline with age, including memory, information processing, and attention (for an extensive overview, see Craik & Salthouse, 2000). However, there are individual differences in the rate of this decline (e.g. Schaie, 1994): some adults show symptoms of age-related cognitive decline at a younger age than others. While research into these individual differences in aging initially focussed on pathological aging, more recently attention has shifted to determinants of normal and successful aging (Baltes & Carstensen, 2003; Rowe & Kahn, 1997).

With respect to normal aging, individual differences in biomedical and sociodemographic factors have been shown to contribute to the age-related variance in cognitive functions. For example, health-related factors, such as subjective health, diabetes, or chronic bronchitis, appear to explain differences in cognitive aging (Colsher & Wallace, 1991; van Boxtel et al., 1998; van Boxtel, Langerak, Houx, & Jolles, 1996). Furthermore, sociodemographic factors, such as mentally demanding jobs and intellectual engagement, have been shown to protect against (non-pathological) age-related cognitive decline (Bosma *et al.*, 2002a; Hultsch, Herzog, Small, & Dixon, 1999) and to delay the onset of pathological symptoms in cognitive disorders, such as Alzheimer's disease (AD) (Glatt et al., 1996; Prencipe, Casini, Ferretti, & Lattanzio, 1996).

The mechanisms by which biomedical and sociodemographic factors moderate the aging of cognitive functions remain unclear, yet knowledge of such mechanisms may be used to develop intervention strategies to slow the aging process. The concept of reserve capacity, or more specifically the concepts of brain reserve capacity (Satz, 1993) and cognitive reserve (e.g. Stern, 2002), provides a model for understanding the protective effect of factors such as education, mental job stimulation, and cognitive activities. In this chapter, we review research examples and support for the concepts of brain and cognitive reserve. Also, we discuss the possibility to increase an older person's reserve capacity and to improve cognitive functioning in later life by stimulating mental activity, in this case by using computers and the Internet as potential sources of mental stimulation.

The reserve concept

The concept of reserve capacity was introduced to explain individual differences in the onset of clinical symptoms after brain damage. For example, Katzman et al. (1989) described older women who showed neuropathological evidence of advanced Alzheimer's disease (AD) at autopsy but who had been healthy and functioning normally until the moment of death. In a review, which has led to a renewed interest in the topic, Satz (1993) described a number of studies that showed differences in symptom onset in both Parkinson's disease and AD between individuals with comparable amounts of tissue damage or neuronal loss. The authors of the cited studies explained their findings in terms of individual differences in brain reserve capacity. Satz suggested that this reserve capacity might alter the threshold of symptom onset, such that individuals may have different degrees of brain damage before symptoms become clinically apparent.

Because there is no direct measure of reserve capacity, investigators often use indirect measures, such as intelligence, education, and brain volume (e.g. Prencipe et al., 1996; Schmand, Smit, Geerlings, & Lindeboom, 1997b; Tisserand, Bosma, van Boxtel, & Jolles, 2001). Next to this lack of a direct measure of reserve capacity, there is also no consensus on the true nature of this concept, and hence an unambiguous definition of the concept has not yet been formulated. For example, Stern (2002) defined it as "reserve against brain damage", while Satz (1993) referred to reserve as a hypothetical construct related to adaptive behavior. Alexander et al. (1997) suggested that cognitive reserve consists of compensatory skills developed in response to disease. Robertson and Murre (1999) considered cognitive reserve to protect cognitive function from deterioration caused by disease, injury, or natural aging. More recently, reserve capacity has been defined more specifically in terms of passive and active brain reserve (Staff, Murray, Deary, & Whalley, 2004; Stern, 2002).

Passive models of reserve

A key element of the model of brain reserve capacity is the assumption of a threshold of damage, beyond which there will be clinical manifestations of brain damage (Satz, 1993; Staff et al., 2004). Thus, in individuals with a supposedly high brain reserve capacity, no clinically noticeable symptoms of damage will occur as long as the individual threshold is not exceeded. Conversely, the same degree of brain damage in individuals with a low brain reserve capacity may result in clinical manifestations. In such a "passive" model, the brain does not recruit mechanisms to actively compensate for damage (Stern, 2002).

Brain reserve capacity is a hypothetical construct and has been operationally defined by proxy measures based on neurobiological indicators, such as brain volume or numbers of neurons or synapses. Mortimer (1997), for instance, provides the following interpretations of brain reserve: "the number of neurons and/or the density of their interconnections in youth when the brain is fully developed", and "the amount of functional brain tissue remaining at any age which determines whether or not one is cognitively intact" (p. 51). Stern suggests that the earliest signs of dementia, such as memory problems, will appear when the number of synapses is reduced beyond a critical level (Stern, 2002). In this sense, individuals with a larger pool of synapses (that is, more brain reserve capacity) can suffer more brain damage before the threshold for symptom onset is reached. Alexander et al. (1997) also mentioned the possibility of a direct link between reserve and brain function at the neuronal level. They suggested that premorbid intellectual ability, a measure they found to be associated with pathophysiological effects of AD, reflects synaptic connectivity among neurons, with a higher premorbid ability being associated with a greater synaptic connectivity.

The results of several studies indeed suggest that anatomical brain variables can serve as measures of brain reserve capacity. For instance, estimated premorbid brain volume appears to be associated with the development of AD. Graves, Mortimer, Larson, Wenzlow, and Bowen (1996) showed that patients with AD with a smaller head circumference, an indirect measure of brain volume, either progressed more rapidly or developed symptoms of AD earlier than patients with a larger head circumference. Schofield, Logroscino, Andrews, and Albert (1997) found that individuals with head circumferences in the lowest quintile had an increased risk of developing AD.

Research into normal aging has also provided support for the use of anatomical variables as proxy measures of brain reserve capacity. For example, Tisserand, Bosma, van Boxtel, and Jolles (2001) found an association between head size and cognitive ability. In their study of adults aged 50 years or older, head size was associated with better performance on measures of intelligence, global cognitive functioning, and speed of information processing. Comparable results were found in a MRI study by MacLullich et al. (2002), who related head circumference to cognitive ability, with larger brain size being associated with better cognitive functioning. Such results suggest that a neuroanatomical correlate, such as brain volume, may indeed be an indicator of reserve capacity, protecting against symptom onset and progression due to normal or pathological aging.

Active models of reserve

Active models of reserve capacity do not assume a 'hardware' representation of reserve, such as specific brain structures, as the passive models do. Instead, these models focus more on the 'software', or the brain functions used to compensate for damage (Stern, 2002). Or, as Mortimer put it: one distinct meaning of reserve is "the collection of cognitive strategies for solving problems and taking neuropsychological tests" (Mortimer, 1997, p. S51). That is, individuals with high levels of reserve can make use of several strategies to attain the same goal and are thus better able to compensate for a loss of brain function. Alexander et al. (1997) suggested that cognitive reserve may reflect a greater availability or efficiency of functional brain systems.

Kliegl, Baltes, and Smith (1987) used the term "cognitive plasticity" to describe the ability to improve cognitive performance. People, both young and old, can improve their cognitive skills by training (Kliegl, Smith, & Baltes, 1989, 1990). Kliegl and Baltes (1987) refer to this ability to improve as 'developmental reserve capacity'. Thus, training may partially restore cognitive capacities that have diminished as a result of normal aging (Kliegl et al., 1989). Consequently, people who train their cognitive capacities regularly, and thereby increase their level of cognitive performance, may be protected against age-related decline. By increasing their level of cognitive functioning, they can sustain more cognitive damage before their threshold for symptom onset is reached compared with individuals with lower levels of cognitive functioning.

The concept of cognitive reserve does not assume a physically determined reserve capacity. Instead, it is operationally defined as the efficiency by which cognitive tasks are executed. Thus, individuals with more cognitive reserve are more proficient in the use of cognitive skills or may use more or different alternative strategies to achieve cognitive goals compared with individuals with a limited cognitive reserve. This proficiency could involve both switching to alternative cognitive strategies to overcome the effects of age-related decline, and recruiting compensatory neural structures to replace damaged pathways (Staff et al., 2004). Indeed, Cabeza, Anderson, Locantore and McIntosh (2002) showed in a PET study that high functioning older adults (presumably individuals with a high level of cognitive reserve) do not recruit the same neurocognitive networks in a memory test as young and low functioning older adults (high functioning older adults showed the same level of performance as young adults, while low functioning older adults performed significantly worse). Low functioning older adults used similar networks to those used by young adults, but apparently not as effectively. This notion of using cognitive skills more efficiently or using alternative skills for the same problem is also used to explain differences between experts and novices. Experts have better-organized knowledge, which allows them to use the same knowledge more efficiently than novices. On the other hand, experts also have more possible strategies at their disposal than novices, which results in a greater flexibility in solving problems. In terms of cognitive reserve, individuals who are 'experts' in using their cognitive abilities are more efficient in dealing with complex cognitive challenges. That is, people with more cognitive reserve use their cognitive skills more efficiently and thus they are better protected against losing their cognitive abilities as a result of brain damage or age-related decline. From a neuroscience perspective, more efficient neural networks are available for the execution of cognitive tasks. Individuals with more efficient neural networks are better able to compensate for extraneous (e.g. brain trauma) or intrinsic (e.g. neurodegenerative disease) challenges to the network integrity.

With this active, functional view of reserve capacity in mind, cognitive reserve has been operationally defined in terms of psychosocial variables, such as intelligence, education, or occupational attainment (e.g. Stern, 2002). This implies that individuals with high levels of intellectual, educational, or occupational attainment can sustain more brain damage before compensation mechanisms fail, and structural brain damage leads to clinical manifestations. This notion is supported by studies showing education and/or intelligence to be associated with the prevalence of AD. In a population survey by Prencipe et al. (1996), prevalence rates of both AD and vascular dementia were higher in individuals with a low educational attainment. Results from the Amsterdam Study of the Elderly (AMSTEL) showed that there is a relation between educational level and the incidence of dementia (Schmand *et al.*, 1997a). In the same population study, intelligence was found to be a more powerful predictor of dementia incidence than educational level. Such results imply that function-related variables are associated with the onset of AD symptomatology.

However, factors that are established early in life, such as educational attainment or intelligence level, are not the only factors to protect individuals from the effect of brain damage or age-related cognitive decline. Factors related to lifestyle, which are dynamic over the course of a lifetime, have also been described in relation to reserve capacity. For example, Hultsch et al. (1999) found a positive relationship between changes in participation in intellectually engaging activities and changes in cognitive functioning in a sample of middle-aged and older adults, who were tested three times in 6 years. A study by Wilson et al. (2002) has confirmed this finding. In this study, people who were more engaged in cognitive activities (that is, activities that require information processing capacity, such as playing games and visiting the library) showed less evidence of cognitive decline at a 4.5-year follow-up measurement: the rate of cognitive decline decreased for each additional cognitive activity people were engaged in. Finally, in the Bronx Aging study, Verghese et al. (2003) found that increased participation in cognitive activities (such as reading and playing games) by individuals older than 75 years of age was associated with a reduced risk of developing dementia.

Thus, these studies suggest that intellectual or cognitively challenging activities are associated with the preservation of cognitive capacity. Possibly, individuals who regularly engage in these challenging activities train their cognitive abilities to an 'expert' level, thereby enlarging their cognitive reserve. This relation between activity level and cognitive capacity has not only been confirmed by studies of intellectual challenges, support was also provided by studies of other everyday activities. For example, Bosma, van Boxtel, Ponds, Jelicic et al. (2002b) reported that older people who participated in three or more mental, social, or physical activities showed less cognitive decline over 3 years than people who did not engage in such activities. In addition, Bassuk, Glass, and Berkman (1999) showed that older individuals with lower levels of social engagement had a greater likelihood of cognitive decline after 3, 6, and 12 years. Christensen et al. (1996) found that inactivity was associated with lower scores for both fluid and crystallized intelligence in older adults. Lastly, Stevens, Kaplan, Ponds and Jolles (2001) found, in a cross-sectional study, that older people who were more physically, cognitively, and socially active performed better on a memory task (delayed recall).

In conclusion, aspects of cognitive reserve that may protect against the onset of age-related cognitive decline or cognitive disorders are established both early in life (e.g. education) and later in life (e.g., engagement in cognitively challenging activities). These dynamic measures of cognitive reserve are modifiable and thus interesting in view of intervention strategies. The abovementioned results imply that it may be possible to boost cognitive reserve by promoting the participation in cognitively challenging activities.

Increasing cognitive reserve: 'Use it or lose it'?

'Use it or lose it'

The notion that continued mental activity may protect against cognitive decline is in line with the 'use it or lose it' principle (Swaab, 1991; Swaab et al., 2002). From a neurobiological perspective, this notion states that the use of neurons and neuronal networks prolongs the efficiency of central nervous system (CNS) activity during life. Swaab reviewed animal studies that showed that activation of neurons did not result in 'wear and tear'. That is, increased metabolic activity does not result in premature cellular aging. Rather, neuronal activity is associated with the preservation of neuronal integrity. Thus, according to Swaab, activation of neuronal circuits may slow down the aging process. Candidate factors to stimulate the CNS may originate from within the organism itself (e.g. through the action of neurotransmitters or hormones), but also from the environment.

Translation of the 'use it or lose it' notion to cognitive functions implies that mental stimulation may have a protective effect against a decline in higher brain functions, especially in later life. This hypothesis is supported by several animal studies, which have shown that enriched environments, which provide a stimulating and challenging habitat, are beneficial to the cognitive functioning of laboratory animals. Warren, Zerweck and Anthony (1982), for example, showed that after exposure to such a stimulating environment, old mice outperformed controls on an incidental learning and a food-seeking task. More recently, Frick and Fernandez (2003) showed that exposure of mice to stimulating objects for 3 hours each day improved spatial memory acquisition (measured with spatial and cued Morris water maze tests). Old female mice performed similarly to young mice, while old control mice had an impaired performance. A final example is a study of Milgram (2003), who investigated the effect of a behavioural enrichment program on old Beagle dogs. This program included housing with mates, regular exercise, and environmental enrichment by adding toys and regular experience with neuropsychological tests. After 2 years in this program, the behaviourally enriched group performed better than the control group on a discrimination and reversal task, suggesting that a prolonged period of cognitive enrichment may help to reverse or delay age-related cognitive decline in dogs. Thus, stimulating cognitive functions seems beneficial to cognitive functioning in later life.

These results are not only consistent with the 'use it or lose it' notion (stimulation of brain functions does not lead to decay of these functions, but rather to maintenance and support), but also with the concept of cognitive reserve. According to this active model of reserve capacity, individuals who learn to use their cognitive skills more efficiently are better protected against symptom onset following brain damage. From a behavioural point of view, the Environmental Enrichment Theory of Schooler (1987) provides a further explanation for the potential beneficial effect of an enriched environment on human cognitive capacities. A more complex environment requires more cognitive effort from the individual. When this effort is rewarded, for example by the beneficial effect associated with learning a new skill, people become more motivated to further develop these intellectual capacities. In addition, they will start using the newly acquired cognitive skills in other situations as well.

We hypothesize that when older adults engage in cognitively demanding activities, they are able to increase their reserve capacity by developing more efficient cognitive skills and (alternate) strategies. As a result, age-related cognitive decline may be postponed or, ideally, even reversed. This hypothesis is supported by the above-mentioned studies, suggesting that engagement in cognitively stimulating activities, such as reading and playing games, is positively related to cognitive functioning in later life. These studies, however, were all observational. None had a controlled, prospective design, so it is not possible to draw a definitive conclusion that these activities are causally related to protection against (age-related) cognitive decline. Causality may even be reversed, that is, individuals with higher levels of cognitive reserve may be more inclined to participate in cognitive activities. This issue can only be satisfactorily resolved in carefully designed, prospective intervention studies.

Cognitive interventions and training to increase cognitive reserve

Several examples of interventions that target cognitive capacities have been described in the literature. For example, Kliegl, Smith and Baltes (1989, 1990) used a testing-the-limits approach to maximize individual performance. In one study (Kliegl et al., 1989), both old and young adults improved their performance after being trained to reach maximal expertise in serial word recall by instruction and practice in the Method of Loci, a mnemonic technique. Other studies of memory training in older adults have generally shown positive effects on memory performance (e.g. Brooks, Friedman, Pearman, Gray, & Yesavage, 1999; Cavallini, Pagnin, & Vecchi, 2003; Moore, Sandman, McGrady, & Kesslak, 2001; Stigsdotter & Backman, 1995). Verhaegen, Marcoen and Goossens (1992) performed a meta-analysis of 33 studies of the effectiveness of mnemonic training in improving the memory performance of older participants. They showed that the pre-to-post-test gain for training groups was significantly larger than the gain for the control and placebo groups. These authors concluded that mnemonic training could enhance the performance of older adults more than retesting and placebo treatment.

Although mainly memory interventions have been investigated, other kinds of cognitive training programs, educational interventions for example (see Schaie, 1994) have been tested for efficacy as well. A 5-hour reasoning or spatial orientation training program, based on their performance status (participants were assigned to the training program for the ability exhibiting decline) reversed cognitive decline in older adults over a 14-year period (Schaie and Willis, 1986). Later, the same authors showed that these interventions actually trained the ability underlying the test, rather than merely test performance (Schaie, Willis, Hertzog, & Schulenberg, 1987). Moreover, the improvement was sustained for 7 years (Kramer & Willis, 2002; Schaie, 1994). In addition, correlations were found between the trained abilities and measures of practical intelligence (Willis & Schaie, 1986) and objective measures of performance on instrumental tasks of daily living (Willis, Jay, Diehl, & Marsiske, 1992), which suggests a transfer of these abilities to daily activities. In a more recent study, Ball and colleagues (2002) designed three types of intervention training: memory training, reasoning training, and speed-of-processing training. Each type of training significantly improved the cognitive abilities that were targeted but no type of training did affect everyday functioning. This suggests that it is possible with specific interventions to improve specific cognitive abilities of older adults. However, everyday functioning draws on multiple cognitive functions. For instance, a daily activity such as grocery shopping involves planning (how to reach the grocery store), memory (which items to buy), information processing (which of the items in the store are relevant), etc. Thus multifactorial interventions (McDougall, 1999; Stigsdotter & Backman, 1995) may be needed in order to stimulate then numerous cognitive abilities known to deteriorate with aging. A potential activity that may qualify for such a multifactorial intervention, and which could be incorporated into the lives of older adults quite smoothly, is learning to use computers and the Internet.

The Internet as an example of multifactorial cognitive training

Cognitive requirements of using the Internet

In order to illustrate which kind of cognitive activities are involved when using the Internet, a hierarchical task analysis (HTA) of the process of 'Web surfing' was conducted (see Table 1). In HTA, a hierarchy of operations and plans is produced to represent a wide range of tasks, including tasks that require adequate levels of cognitive activity (Kirwan & Ainsworth, 1992). The current task was analyzed to chart the cognitive processes that underlie operations that are needed to find information on the World Wide Web. Health

Table 1 *Hierarchical task analysis of the process of 'web surfing' on a Apple computer*

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
1. Switch on computer	1.1 Press on/off button				
2. Lauch Internet Explorer	2.1 Open Apple-menu	2.1.1 Move pointer to Apple	2.1.2 Click		
	2.2 Click "Internet Explorer"	2.2.1 Move pointer to "Internet Explorer"	2.2.2 Click		
3. Search a relevant site	3.1 Go to a search engine	3.1.1. Type URL	3.1.1.1 Move pointer to address bar	3.1.1.2 Click address bar	3.1.1.3 Type
	3.2 Enter a search	3.2.1 Type (a) search word(s)	3.2.1.1 Move pointer to field	3.2.1.2 Click field	3.2.1.3 Type
	3.3 Choose a relevant site	3.3.1 Read results of search			
		3.3.2 Choose the most relevant site	3.3.2.1 Move pointer to title of site	3.3.2.2 Click	
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	3.4 If necessary: check next result page	3.4.1 Click "next page"	3.4.1.1 Move pointer to "next page"	3.4.1.2 Click	
		3.4.2 Return to 3.3.1			
4. Find relevant information	4.1 Scan site for relevant information				
	4.2 If necessary, return to result page	4.2.1 Click "back" button as often as needed	4.2.1.1 Move pointer to "back" button	4.2.1.2 Click	
		4.2.2 Return to 3.3			

consultation is a typical example of Internet use by older adults (e.g. (Lindberg, 2002; Morrell, Mayhorn, & Bennett, 2000; Stronge, Walker, & Rogers, 2001). Therefore, the goal of the task under analysis here was to find information about diabetes, a common disease in the older population, by using a standard search engine. The cognitive processes and examples of their matching operations are presented in Table 2.

Table 2 *Cognitive skills that are mobilized when using the Internet with examples of matching operations*

Cognitive skill	Matching operation
Long term (procedural) memory	Remembering the appropriate procedure to launch a browser
Short term or working memory	Keep track of already attended information and already performed actions
Executive functions	Structuring necessary actions in the correct order
Visual search	Finding relevant information cues on a Web page
Information processing	Evaluate which information on a Web page is relevant
Attention	Focus on relevant cues on a Web page and ignore irrelevant cues

In addition to the cognitive activities that were evident from our task analysis, other processes can play a role in finding information on the Web, such as problem solving and concept formation (Stronge, Walker, and Rogers, 2001). Problem solving is defined as a process of assembling an appropriate sequence of component procedures (or operators) to accomplish a goal (Carlson & Yaure, 1990), and is related to the process of behavioural planning mentioned in our task analysis. Concept formation is needed when one deals with computer and Internet-related concepts, which are used as metaphors to facilitate interface mastery (e.g. 'desk top', 'directories', 'drag-and-drop'). This process of concept formation is related to the concept of schemas, mental frameworks for representing knowledge. These frameworks are extended with experience, so when an individual does not have any experience with computers and the Internet, related concepts are not organized yet and these concepts are hard to understand.

Holt and Morrell (2002) mentioned the concept of processing speed in the context of presentation speed in Internet training. They suggested that information on the Internet should be presented in a self-paced fashion to allow the user to modify speed of processing. Two mechanisms have been described as central to the processing-speed theory of differences in cognition in adults and can also be applied to this context (Salthouse, 1996) — the limited time mechanism and the simultaneity mechanism. The latter mechanism in particular can be applied to Internet-related cognitive processes. This mechanism is based on the idea that products of earlier information processing steps may be lost by the time later steps are completed. For example, when searching for information about diabetes on a website, a person may have to click on several links on the homepage before the right page of the website is found. According to the simultaneity principle, the person may forget whether he or she has clicked a certain link or not and therefore has to repeat the process, clinking on the link. Spatial orientation is also important. Spatial memory and spatial ability tend to decline in humans with advancing age (Kelley & Charness, 1995). Because of the hypertext-based nature of websites, especially older users may have difficulties in keeping track of where they are in cyberspace (Lin, 2003). Web surfing thus will specifically stimulate skills related to spatial orientation and source monitoring and will thereby provide a cognitive challenge for older users.

In summary, searching for information on the Internet involves the use of skills from different cognitive domains. Using the Internet is a challenge for older adults, because information technologies are often unfamiliar to them and the efficiency of their cognitive functions has diminished with age. According to Rowe and Kahn (1997), such high cognitive functional activity and active engagement with life are essential to successful aging. We argue that stimulating older adults to use the Internet may be a suitable method to promote the usage and development of cognitive skills and thereby increase cognitive reserve.

A number of studies show that older adults experience specific problems with learning to use information technology and Internet services — they are slower, make more errors, and need more steps to reach their goals (Czaja & Sharit, 1993, 1997; Kelley & Charness, 1995; Mead, Jamieson, Rousseau, Sit, & Rogers, 1996; Mead, Spaulding, Sit, Meyer, & Walker, 1997; Walker, Millians, & Worden, 1996). Despite these difficulties, older adults are able and willing to learn such a new skill and also tend to enjoy it (Czaja, 1996; Morrell et al., 2000; Rogers & Fisk, 2000). This means that it is important to design suitable guidelines for training older adults to use computers and the Internet (Holt & Morrell, 2002; van Gerven, Paas, van Merrienboer, & Schmidt, 2000).

Computer- and Internet-based intervention studies

Although some authors already suggested that computers and the Internet could potentially improve the quality of life for older adults (Czaja, 1996; Mead, Batsakes, Fisk, & Mykityshyn, 1999; Morrell et al., 2000), few attempts have been made to experimentally study the impact of the use of computers and the Internet on cognitive capacity, social networks, and autonomy of older adults. In an early study, Danowski and Sacks (1980) installed a computer terminal in an urban retirement hotel on which residents could play games and communicate with other users. After a follow-up period of 3 weeks, participants said they felt more self-confident and less alone. Czaja, Guerrier, Nair and Landauer (1993) provided independently living older adults with a communication terminal at home. This terminal contained a simple electronic mail system, a text editor, and access to news, movie reviews, health information, and entertainment. After using this terminal for 6 months, the participants had improved social interaction skills. Sherer (1996) provided nursing home and day-care centre residents with a computer in a common room. Participants in the experimental group could use this computer both independently and under supervision. A control group was promised special computer training at a later stage. After using the computer for six months, self-esteem and satisfaction with life of the residents in the experimental group had increased. White et al. (2002) showed trends toward decreased loneliness and decreased depression in intervention subjects compared with controls after a five-month period of Internet use in a group of older nursing home residents.

These studies demonstrate a potential effect of computer and Internet use on personal and social factors such as self-esteem, loneliness, and social interaction. However, none of these studies included measures of cognitive function. A study by McConatha, McConatha and Dermigny (1994) included cognitive functioning in a small computer-based intervention study. They taught fourteen elderly long-term care patients to use online computer services such as electronic mail, bulletin boards, games, and information sources. After this training, participants used the computer system for a 6-month period. The participants had higher scores on a Mini-Mental State examination, a crude screening instrument for cognitive disorder, greater independence in activities of daily living, a measure of functional ability, and lower depression scores.

Thus, the results of a number of studies suggest that using computer services may have a positive effect on social and cognitive functioning in old age, but firm evidence is still lacking. Most of these studies used rather small samples of participants, recruited from nursing homes or other communities, and did not always include control groups. Moreover, none of the studies explicitly tested the effect of the use of computer and Internet services on cognitive functioning. To test the hypothesis more reliably, a randomized controlled study with independently living, healthy older adults is necessary.

Discussion

In this article, we followed the line of argument that people possess a certain amount of cognitive reserve, which protects them from (age-related) cognitive decline. Both animal and human studies suggest that this reserve capacity can be increased by (continued) cognitive activity in later life. When individuals use their cognitive functions more extensively, for instance by engaging in cognitive demanding activities and thereby learning to employ cognitive abilities more efficiently, their overall cognitive performance will improve. This higher level of cognitive performance entails a higher amount of cognitive reserve, which may protect individuals from deterioration of cognitive functions as a result of brain damage, or even of normal aging. Delaying age-related cognitive decline helps older adults to remain independent in their everyday functioning for a longer time. This could, in turn, result in a reduction of the overall consumption of expensive health care.

We argue that one way to achieve a higher level of cognitive activity in the older population is to encourage older individuals to use the Internet. Besides the opportunity to train cognitive functions, the Internet has many other practical advantages for older adults as well. First of all, the maintenance of social contacts is facilitated by the Internet (Czaja, 1996; Mead et al., 1999; Morrell, 2002; Morrell et al., 2000). As a result, using the Internet could increase the perception of social support (Cody, Dunn, Hoppin, & Wendt, 1999; Morrell, 2002). Secondly, by using the Internet, individuals can access a variety of information sources that are of particular interest to older individuals, such as practical information about relevant issues, such as health (Cody et al., 1999; Morrell et al., 2000), hobbies, or other fields of interest (Czaja, 1996). Using these information sources could promote autonomy in older adults, particularly when physical limitations restrict their social engagement. Thirdly, there is evidence that the Internet has psychological benefits, such as increased well-being and sense of control (Morrell, 2002). Finally, by facilitating performance of routine tasks, such as shopping and financial management, the Internet may enhance the autonomy of older people, especially among those who are restricted in their mobility (Czaja & Lee, 2003)

In conclusion, the Internet has many potential benefits that could help older adults to live more independently. These benefits include both direct, practical benefits, and also more long-term benefits in terms of improved cognitive abilities and delayed age-related decline. Studying the impact of using the Internet on the lives and cognitive performance of older adults, for example through studies with controlled designs, will provide a better understanding of the process of successful aging and may be used to design more effective techniques to slow the process of cognitive aging.

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Chapter 3

Methods of the intervention study

In six of the experimental chapters of this thesis (Chapters 4 to 9), data of the main intervention study were used. Therefore, we chose to present the method sections dealing with information about the participants and the procedure of this study in a separate chapter.

Participants

For the intervention study, we aimed at recruiting 240 participants in four separate groups. Due to this large group of participants it was decided to recruit the participants in two successive periods of twelve months. Invitation flyers were randomly sent to older adults from the Maastricht city register. Both participants with and without interest to learn to use computers and the Internet were invited to respond to the flyer. Individuals were included in the study if they were aged between 64 and 75, considered themselves to be healthy and were sufficiently mobile to travel independently to the research centre. Exclusion criteria were general mental functioning in a range suspect of a cognitive disorder (score below 24 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975)) and prior active computer experience. Also, participants were to be willing to sign a form stating that they would refrain from any self-initiated computer use or computer lessons in case they were assigned to one of the non-intervention groups for the duration of this study (i.e. twelve months). Each participant signed an informed consent form. The Medical Ethics Committee of Maastricht University Hospital approved the study.

To be able to separately account for effects of using a computer and the Internet for twelve months, of the administered computer training, and of participant's interest in learning to use computers it was decided that exposure to the intervention was to be compared to three different control groups: one group consisted of individuals without a particular interest in computers and Internet use, and two different groups consisted of individuals with this interest. Comparison with the first group was deemed necessary to prelude a potential bias in intervention results due to latent variables associated with computer interest. One of the latter two groups consisted of individuals who received the same training as individuals in the intervention group, and the other group consisted of individuals who were not trained in computer and Internet skills. This distinction was made to prevent the possibility that the computer training per se would be responsible for an intervention effect. Participants who were interested in the intervention were thus randomly assigned to the Intervention Group, the Training/No Intervention Group or the No Training/No Intervention Group, respectively. Participants who were not interested were always assigned to the Control Group.

Procedure

A total of 6,054 individuals received the flyer, and 1,016 persons applied for more detailed information. After reading this detailed information, 366 individuals who were interested in participation called the research centre for a screening interview by telephone.

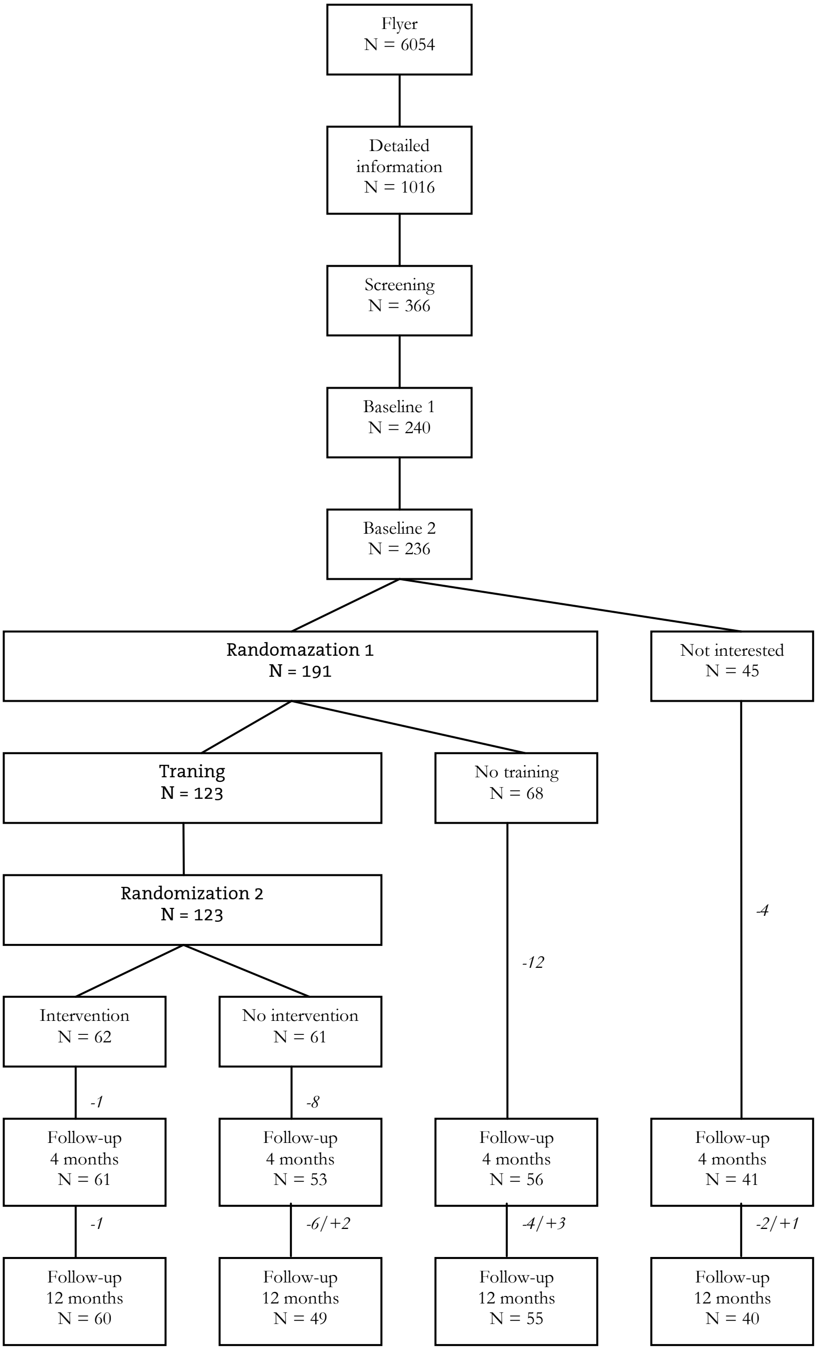
Two-hundred-and-forty individuals were eligible for the study according to the inclusion criteria and could be included with respect to stratification to age, sex and level of education. These individuals were familiarized extensively with the possible outcomes of the randomization procedure. That is, all participants were aware of the fact that there was a possibility of receiving a computer for twelve months, but they were also aware of the possibility of having to refrain from computer use for this period. Also, participants were informed they could decide to quit the program at any moment. All participants agreed with these conditions of the study. One-hundred-and-twenty-six people were excluded from the study or did not wish to participate, because of computer experience (n=54), health related problems (n=14), experience with tests from the test battery (n=11), because they were not willing to refrain from computer use during the study (n=4), lack of a cable TV connection at home (which was required for the Internet connection) or lack of space for a personal computer (n=2), or no specific reason (n=41). After the first baseline administration, four participants dropped out of the study due to health problems, being 'too busy' or put of by the test procedure, or a score of below 24 on the Mini Mental State Examination. The participants who were included were scheduled for two baseline administrations of the cognitive test battery. This dual baseline administration of the tests (with one to two weeks in between) was applied to familiarize the participants with the test procedures and to minimize procedural learning of the tests during the study period. For this reason, cognitive data from the first baseline measurement were discarded. The test battery was administered again after four and twelve months, using parallel test versions. In addition, a questionnaire was administered at all test occasions covering several domains of wellbeing, autonomous functioning, and the use of everyday technology.

Initial recruitment did not yield sufficient participants for the Control Group, so again an invitation letter was sent out to 585 new people from the municipal registry to recruit only additional participants who were not interested in computers and the Internet. By means of this second recruitment an extra number of 15 individuals agreed to participate in this group. After these two recruitment procedures the number of participants in the Control Group after baseline was kept at 45.

After the baseline test administrations, participants with interest in learning to use computers and the Internet (n=191) were randomly assigned to three groups in a two-phased randomization procedure (for a schematic overview of the recruitment and randomization procedure, see Figure 1). First, two thirds of these participants (n=123) were selected for a three-session training course in general computer and Internet skills. The remaining participants did not receive this training and were assigned to the No training/No intervention Group.

The participants in the training condition were scheduled for three four-hour training sessions during a period of two weeks. In these sessions, participants were introduced to and could practice with a personal computer (Apple Macintosh) and its operating system (MacOS 9), customary software applications (for instance a word processor) and several Internet applications (i.e. an Internet browser and an e-mail program). Under supervision of an experienced teacher, participants received general information and were instructed

Figure 1 *Flowchart of the recruitment and two-phase randomization procedure*



about how to perform basic computer and Internet assignments from a custom-made course book. Ample time was available at each meeting to practice with several applications at participants' own aspiration. After this training, participants were randomly assigned to the Intervention Group (n=62) and the Training/No intervention Group (n=61). For a description of the baseline background statistics, see Table 1.

Table 1. *Mean (SD) age and level of education (1-8), percentage of women and mean (SD) score on the Mini Mental State Examination (MMSE) for each group*

Group	Age	Level of education	Sex	MMSE
Intervention	68.98 (2.68)	3.70 (1.49)	57,7%	28.18 (1.35)
Training/No intervention	69.08 (2.87)	3.78 (1.80)	54,9%	27.96 (1.46)
No training/ No intervention	68.85 (2.80)	3.93 (1.54)	63,6%	28.36 (1.38)
Not interested	69.75 (3.13)	4.08 (1.71)	60,0%	28.73 (1.26)

Participants in the Intervention Group were equipped with an up-to-date personal computer (Apple iMac) with high-speed Internet access in their homes (cable) for a twelve-month period. They received no specific instructions but were stimulated to use the computer in accordance with their own personal needs. Internet-related assignments through e-mail (once every two weeks in the first four months, once every month in the remaining period of the study) were given to promote continuous use of the computer facilities and to track down participants who made insufficient progress with respect to their computer skills. These assignments were of increasing difficulty. Examples of early assignments are to reply to an e-mail message or to find easy accessible information on a specified website. An example of a more difficult assignment is finding information about a book in an unspecified online library catalogue. A help desk with remote support facilities ('remote desktop') was available for all questions related to computers and Internet use during the project to be able to immediately help participants with technical or usability problems.

Participants in all no-intervention groups were to refrain from computer use during the intervention interval of twelve months, as they agreed to by signing the form mentioned above. Compliance to this agreement was again confirmed by signing a statement at the end of the study. Participants in the no-intervention groups could win one of six personal computers in a raffle at the end of the study period. Participants were free to decide to quit the project at any time.

Nineteen participants dropped out before the four-month follow-up, and six participants were not available for the four-month follow-up measurements (one participant was absent for a long time, one did not like the tests and questionnaires, one was disappointed about the randomization result, one was too worried about his/her own memory performance, one could not be reached and one gave no reason). Another thirteen participants dropped out before the twelve-month follow-up measurements. Participants gave various reasons for dropping out (time constraints (n=7), health problems (n=5), disappointed about randomization (*n*=5), partner's health problems (*n*=2), partner died (*n*=2), bought/received computer (*n*=2), private/family problems (*n*=2), being absent for a long time (*n*=1), died (*n*=1), moved away (*n*=1), computer training was too much (*n*=1), and other reasons (*n*=3)).

Thus, baseline tests were administered to 236 participants and complete follow-up data were available from 204 participants. Some participants did not complete all cognitive tests or questionnaires at some point, due to several reasons (e.g. technical problems with test administration, or personal reasons to not answer some of the questions). This resulted in available data of slightly different numbers of participants for different outcome measures.

Reference

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Chapter 4

The effects of computer training and Internet usage on cognitive abilities of older adults: A randomized controlled study

Under revision

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Abstract

According to the concepts of 'use it or lose it' and cognitive reserve, cognitively challenging activities may boost the cognitive abilities of older adults. The use of a computer and the Internet provides divergent cognitive challenges to older persons, and positive effects of computer and Internet use on the quality of life were found in earlier studies. We investigated whether guided prolonged computer use by healthy older adults (64-75) may be beneficial to cognitive ability in a randomized controlled study. The intervention consisted of a brief training and subsequent use of a personal computer with an Internet connection at home for a twelve-month period. 191 Participants were randomly assigned to the Intervention Group, the Training/No intervention Group, and the No training/No intervention Group. A fourth group consisted of 45 participants with no interest in computer use. The effect of the intervention was assessed using a range of well-established cognitive instruments that probed verbal memory, information processing speed and cognitive flexibility. Data were collected at baseline and after four and twelve months. The results showed that intensive interaction with a personal computer and with standard software applications had no effect on the cognitive measures; no differences in changes in cognitive parameters over time were found between groups. It is concluded that learning to use a computer and the Internet has no cognitive benefit for healthy, community-dwelling older adults. The implications of these findings for future studies that use cognitive challenge to counteract usual cognitive aging are discussed.

Cognitive abilities tend to decline with age (for an extensive overview, see Craik & Salthouse, 2000). An important question, however, is whether this process is reversible when potential causative factors are manipulated. Several studies have suggested that engagement in cognitively challenging activities is associated with maintenance or even improvement of cognitive skills and seems to protect against age-related cognitive decline. For instance, Hultsch, Herzog, Small and Dixon (1999) found a positive relationship between changes in participation in intellectually engaging activities and changes in cognitive functioning in middle-aged and older adults who were tested three times in six years. Comparable observations were made by Wilson et al. (2002), who found that the rate of cognitive decline of people aged 65 and older in 4.5 years decreased for each additional cognitive activity they reported to be engaged in (which were defined as activities that require 'information processing capacity'). Also, participants in the Bronx Aging Study, aged 75 and older, who engaged more often in activities such as reading and playing games demonstrated a lower risk of developing dementia (Verghese *et al.*, 2003). In other studies, more general measures of activity, such as participation in everyday mental, social or physical activities, were found to be associated with protection from cognitive decline (e.g. Bosma *et al.*, 2002; Christensen *et al.*, 1996). These studies all suggest that intellectual and cognitively challenging activities are related to the preservation of cognitive capacity.

Results such as those described above suggest that it may be possible to improve cognitive functioning by promoting the participation of older persons in cognitively challenging activities. This notion is in line with Swaab's 'use it or lose it' principle (Swaab, 1991), which is based on neurobiological findings in animals that the use of neurons and neuronal networks prolongs the efficiency of central nervous system (CNS) activity during life. According to Swaab, candidate factors to stimulate the CNS may originate from within the organism, but also from the environment. When the notion of 'use it or lose it' is translated to a functional level, this would imply that mental stimulation may counteract the reduced efficiency of higher brain functions that comes with age. This has actually been found in several animal studies in which enriched or challenging environments proved to be beneficial to the cognitive functioning in aged laboratory animals (e.g. Frick & Fernandez, 2003; Milgram, 2003). Such findings are not only consistent with the 'use it or lose it' notion, but also to the concept of cognitive reserve, which assumes that individuals with more elaborate cognitive strategies are better protected against symptom onset following brain damage (Stern, 2002).

Several examples of interventions that specifically target cognitive capacities of older adults have been described in the literature. Such studies involved memory training (e.g. Stigsdotter & Backman, 1995; Valentijn *et al.*, 2005) or mnemonic techniques (Ball *et al.*, 2002; Verhaeghen, Marcoen, & Goossens, 1992), all of which had positive effects on memory performance to a variable extent. Apart from memory, other cognitive abilities, such as reasoning, spatial orientation and speed of processing (Ball et al., 2002; Schaie & Willis, 1986) have been taught successfully and shown to improve in older adults.

The studies cited above suggest that it is possible to improve cognitive functions of older adults with specific, dedicated interventions. However, in order to function independently in everyday life, multiple cognitive functions are drawn upon. For instance, a daily activity such as grocery cooking involves planning (the order of adding the ingredients), memory (which ingredients to add), information processing (understanding the preparing instructions), etc. Therefore, to stimulate cognitive abilities known to deteriorate with age in a more general fashion, interventions that target multiple cognitive domains simultaneously may be called for (Stigsdotter & Backman, 1995).

The use of the Internet may qualify as a candidate activity in a multifactorial intervention. It provides an intellectually challenging activity, which is intrinsically rewarding because Internet based services may have particular benefits for older persons (e.g. Cody, Dunn, Hoppin, & Wendt, 1999; White *et al.*, 2002). In order to use Internet services such as Web surfing or e-mail, many of the cognitive abilities that are drawn upon for everyday functioning are recruited. For instance, long-term or procedural memory is required to reproduce the routines needed to use a computer program, e.g. to launch a Web browser, and to execute specific commands in that browser. Short-term memory, or working memory, is activated to keep track of information already attended or to decide on the next action to take. Executive functions come into play in order to sort necessary actions into the correct order. Visual search, information processing and attentional processes are recruited in order to find relevant cues, to evaluate which information on a Web page is relevant within a given context, and to focus on those cues while ignoring or inhibiting irrelevant cues.

Very few attempts have actually been made to study the impact of computer and Internet use on the cognitive abilities of older adults. Several broader studies showed that psychosocial measures, such as self-confidence, loneliness, social interaction, satisfaction with life and depression, could improve as a result of learning to use computers and the Internet (e.g. Cody et al., 1999; White et al., 2002). A limited number of studies have actually focused on the impact of computer and Internet use on cognitive functioning as the primary outcome. McConatha, McConatha and Dermigny (1994) showed that, in a small sample (N=14) of long-term care residents aged between 59 and 89, the score in the Mini-Mental State Examination (MMSE; a broad omnibus test of cognitive function) and Activities of Daily Living (ADL), and depression scores improved after using an on-line computer service for six months. This service consisted of e-mail, access to a digital encyclopaedia, bulletin boards, games and other educational and recreational applications. Comparable results were found in a subsequent study, where 29 nursing home residents, aged 50 and older, were divided into a computer training group and a control group (groups were matched in terms of ability to take care of daily needs, cognitive functioning and depression level) (McConatha, McConatha, Deaner, & Dermigny, 1995). Participants in the training group used the same on-line computer service as had been used in the previous study and participants in the control group participated in regular nursing home recreational and educational activities. After six months of using the computer service, participants in the computer training group improved in MMSE, ADL and depression scores, while the control group remained unchanged. In sum, circumstantial evidence indicates that learning to use a computer and the Internet in later life may have beneficial effects on the cognitive ability of older individuals. However, a number of factors could possibly affect the results of Internet-based intervention studies such as described above. For instance, as participation in such an intervention is on voluntary basis, selection bias may have occurred, i.e. the fact that individuals are interested in information technology may affect the outcome variables of the study, for example as a result of differences in motivation with respect to task performance. There may also have been an effect of computer training apart from the actual subsequent period of computer use. Therefore one should account for both the effect of initial computer training and for the effect of participants' interest in learning to use these facilities in order to be able to exclusively study the effect of using computers and the Internet for a period of time. To date systematic studies on this topic are not available.

Because many of the aforementioned cognitive abilities needed to use the Internet decline with advancing age (see Craik & Salthouse, 2000), combined with the fact that information technologies are often unfamiliar to older adults, it can be expected that using the Internet provides a cognitive challenge to older people. We hypothesize that engaging in such a cognitively challenging activity will stimulate older adults to develop more efficient cognitive skills and (alternate) strategies for daily life task requirements. If proven successful, this study may support the notion that age-related cognitive decline could be counteracted by aspecific mobilization of cognitive resources.

We conducted a randomized controlled intervention study to test the aforementioned hypothesis. A large group of participants with interest in computer usage was recruited from the general population and they were randomly assigned to three conditions in which a cognitive challenge (an intervention that consisted of computer and Internet use for twelve months) was present, or not. In addition, a fourth group with no interest in computers or the Internet was recruited to check for several sources of potential confusion. A comprehensive test battery consisting of standard tests of several domains of cognitive functioning was administered at baseline and after four and twelve months. This design enables a systematic approach to the question of whether complex cognitive activity that is practiced on a regular basis in daily life can be beneficial to the cognitive function of older persons.

Methods

For information about the participants and the procedure of the intervention study, see Chapter 3. A few participants did not complete all questionnaires, which resulted in CFQ data of 231 participants at baseline and complete follow-up data of 196 participants.

Measures

Verbal memory. The Visual Verbal Learning Test (VVLT) (van der Elst, van Boxtel, van Breukelen, & Jolles, 2005) was used to measure verbal memory and learning. In this test, fifteen monosyllabic, low-associative words are presented one after another on a computer screen. After the presentation, participants were asked to recall as many words as possible without any time or order constraint (immediate recall). This procedure was repeated five times with the same list of words. Twenty minutes after the recall of the fifth trial, the participants were once more asked to recall as many words as possible (delayed recall). The score in the first trial of the immediate recall, the sum of the scores in the first three trials and the delayed recall score were used for this study. In addition, the difference between the maximum score in any of the five trials and the score in the first trial was used as an indication of verbal learning capacity.

Psychomotor speed. To measure psychomotor speed, the Motor Choice Reaction Time test (MCRT) (Houx & Jolles, 1993) was included. This test is administered with a six-button panel, containing one red button and five white buttons, laid out in a semicircle around the red button. The participants were asked to hold down the red button with the index finger of the preferred hand as long as no white button was lit. As soon as one of the white buttons was lit, the participants were to release the red button and then press the lit button (or a button adjacent to it) as quickly as possible. After this, the red button had to be held down again. The MCRT involved three conditions. In the first condition (simple reaction time), only the upper white button was lit. In the second condition (choice reaction time), one of the three upper buttons was lit. In the third condition (incompatible choice reaction time), one of the three upper buttons was lit, however, the button immediately to the right of the lit button was to be pressed. Two variables were of interest for the purposes of this study. Firstly, the difference between the median response times of the second and the first condition was used as an indication of response selection. Secondly, a measure of inhibition of a prepotent response (Kornblum, Hasbroucq, & Osman, 1990) was provided by the difference between the third and the second condition.

General cognitive speed. The Letter-Digit Substitution Test (LDST) (van der Elst, van Boxtel, van Breukelen, & Jolles, in press) was used to measure the speed of processing general information. This test is a modification of the Symbol-Digits Modalities Test (Lezak, 1995). A code is provided at the top of a sheet of paper that couples the numbers 1 to 9 with random letters. Participants were asked to fill in on the rest of the sheet as many corresponding numbers in boxes that contained only letters as possible in 90 seconds.

Cognitive flexibility. The Concept Shifting Test (CST) (Vink & Jolles, 1985) was used to measure cognitive flexibility. This test consists of three sheets of paper with 16 small circles that are grouped in a larger circle. On the first sheet, numbers appear in the small circles in a fixed random order. Participants were asked to cross out these numbers in the right order as fast as possible. Instructions for the second sheet were identical to those for the first sheet, except that on this sheet letters appear in the circles. On the third sheet, participants had to alternate between numbers and letters. The time needed to complete each of the sheets was recorded. The mean of the scores for the first and second sheets was used as a measure of simple speed, and the difference between the score for the third sheet and the mean of the scores for the first and second sheets was used as an estimate of the slowing due to the shifting between two concepts (numbers and letters), i.e. cognitive flexibility.

Attention. The Stroop Colour Word Test (SCWT) (Houx, Jolles, & Vreeling, 1993) was used as a measure of selective attention and susceptibility to interference. The test contains three cards. On the first card, colour names are printed in four lines of ten words each. Participants were asked to read the names aloud as fast as possible. On the second card, coloured patches are printed in the same layout as the words on the first card. Here, participants had to name the colour of each of the patches as fast as they could. On the third card, colour names are printed in incongruously coloured ink. Participants had to name the colour of the ink the words were printed in as fast as possible. The time needed to complete each of the cards was recorded. Two variables were computed: the mean of the scores for the first two cards as an indication of simple speed, and the difference between the score for the third card and the mean of the scores for the first and second cards (the interference score) was used as a measure of the capacity to inhibit a habitual response (reading the word), which reflects selective attention.

Cognitive failures. The Cognitive Failure Questionnaire (CFQ) (Broadbent, Cooper, FitzGerald, & Parkes, 1982) was included to measure subjective cognitive functioning. It has been validated and adapted for the use in a Dutch population (Merckelbach, Muris, Nijman, & De Jong, 1996). This questionnaire consists of 25 items that measure the frequency of failures within several cognitive domains (e.g. attention, memory and planning) rated on a five-point scale. The sum of the scores for these items was used as the dependent variable, a higher score indicating more cognitive failures.

Measures of computer use To measure the actual involvement of individuals in the Intervention Group in computer-related activities at both the four-month and twelve-month follow-up moments, participants were asked to indicate how many hours per week they had used the computer and the Internet.

Statistical analyses

Statistical analyses were performed with SPSS version 11 for Apple Macintosh. ANOVAs and Chi-square tests were conducted for baseline comparisons of all dependent variables, the MMSE score and demographic variables (age, sex, education and income as a measure of social economic status) in order to study differences between the four groups. General Linear Model (GLM) with repeated measures analysis of variance was used to study the effect of the intervention. Analyses were conducted with group as between-subject variable (four levels: Intervention, Training/No intervention, No training/No intervention and Control Group) and time as a within-subject variable (three levels: second baseline, four month follow-up and twelve month follow-up). Contrasts were defined to compare changes in performance over time (between the three measurements) of the four groups. Age, level of education, sex, and monthly income were used as covariates. We were especially interested in the interaction of time and group, as this interaction shows whether the groups differed from one another with respect to changes in the dependent variables, for example as a result of the intervention. Data of participants who completed all measurements of the particular test were included in the analyses. Therefore the number of complete cases is not exactly identical for all measures. All analyses were repeated with only the individuals in the Intervention Group to account for the extent of computer use. In these analyses the between-subject variable 'extent of computer use' had two levels: light and heavy. This variable was calculated by using a median split method on the number of hours per week participants said they used their computers at the twelve-month follow-up moment. In this case the median was 7.5 hours, so participants who reported using their computers 7 hours per week or less were labelled 'light users' and participants who reported using their computers 8 hours per week or more were designated 'heavy users'. All variables that were included in the analyses were first checked for normal distributions, missing values and outliers. Distributions were considered suitable for the analyses. All analyses were done with and without extreme values and also with replacement of extreme values by the highest value in the normal range. All statistical analyses were performed with p=.05 as significance level.

Results

Baseline comparisons

At baseline, the four groups did not differ with respect to age, sex, level of education, monthly income and score on the MMSE. When the participants who were interested in the intervention were compared with participants who were not interested, differences were found with respect to the score in the MMSE ($F(1,231)=4.321$, $p=.04$) and the CFQ ($F(1,226)=4.118$, $p=.04$): interested participants had lower scores in the MMSE but reported fewer cognitive failures. These differences were not found in the analyses in which participants who dropped out had been removed from the sample.

Baseline comparisons of participants who dropped out of the study at some point with participants who completed all test administrations showed differences with respect to level of education ($F(1, 229)=4.129$, $p=.04$) and the score in the MMSE ($F(1,234)=4.097$, $p=.04$) Participants who dropped out had lower levels of education and a lower score in the MMSE.

Computer use

At the four-month follow-up measurement, on average participants reported using their computers 8.7 hours per week ($SD=5.8$). At the twelve-month follow-up moment, this average use was 8.3 ($SD=6.2$) hours per week. The difference between month four and twelve was not statistically significant. Of the time participants used their computers, they spent 7.0 ($SD=5.6$) hours per week on the Internet at the four-month follow-up moment, and 6.5 ($SD=5.6$) hours per week at the twelve-month follow-up moment. Again, the difference between the two moments of measurement was not statistically significant.

Effects of the intervention

Table 1 gives an overview of main effects of group on the three measurements and of the interaction between group and time. Main effects of group were found for the summed score on the first three trials of the VVLT, the flexibility score of the CST and the simple speed measure of the SCWT. Pair wise comparisons revealed that participants in the Intervention Group showed higher total scores in the VVLT ($p<.01$) over time than participants in the Training/No intervention Group. Also, participants in the Intervention Group showed better flexibility scores in the CST compared with the Training/No

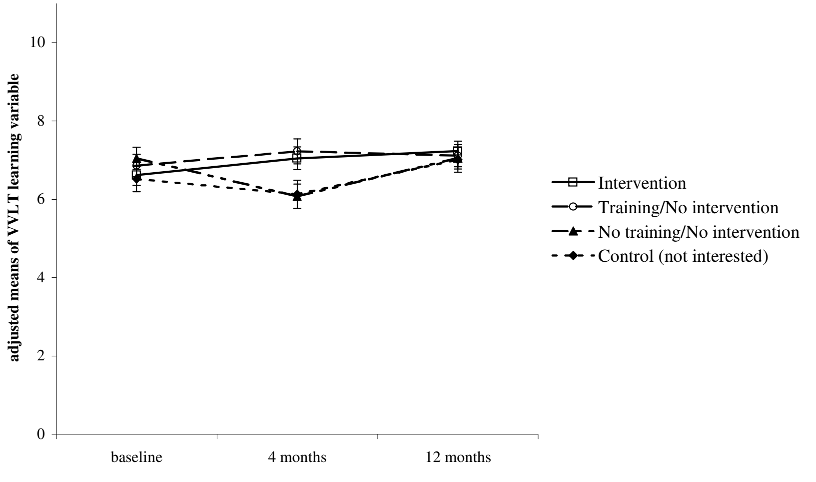
Table 1 *Means (SD) for all cognitive variables at each measurement moment for the four groups, main effects of group and group * time interactions*

	Training/ Intervention	Training/ No intervention	No training/ No intervention	Control Group	Overall group effect p-value	Group*time effect p-value
MMSE	N=60	N=47	N=52	N=39	0.09	0.69
Baseline	28.18 (1.33)	27.95 (1.44)	28.21 (1.45)	28.62 (1.28)		
12-month follow-up	28.38 (1.08)	28.36 (1.28)	28.40 (1.13)	28.64 (1.18)		
VVLT first trial	N=60	N=47	N=52	N=39	0.14	0.14
Baseline	6.55 (2.13)	5.80 (1.81)	5.90 (1.69)	6.22 (1.95)		
4-month follow-up	6.62 (2.26)	5.91 (1.81)	6.90 (2.11)	6.81 (2.28)		
12-month follow-up	6.69 (2.23)	6.36 (1.84)	6.52 (1.70)	6.62 (2.03)		
VVLT sum of three trials	N=60	N=47	N=52	N=39	0.04*	0.51
Baseline	27.02 (5.55)	25.12 (5.56)	25.97 (4.48)	26.29 (5.73)		
4-month follow-up	28.18 (5.68)	25.76 (5.87)	28.37 (5.61)	28.10 (6.23)		
12-month follow-up	29.20 (5.61)	26.81 (4.67)	28.38 (5.14)	27.82 (5.86)		
VVLT delayed recall	N=60	N=47	N=52	N=39	0.29	0.57
Baseline	11.18 (2.84)	10.05 (3.18)	10.84 (2.57)	10.71 (3.07)		
4-month follow-up	12.00 (2.76)	11.11 (3.02)	11.49 (2.37)	11.29 (3.32)		
12-month follow-up	12.38 (2.31)	11.51 (2.93)	11.90 (2.23)	11.74 (2.41)		
VVLT verbal learning	N=60	N=47	N=52	N=39	0.34	0.04*
Baseline	6.69 (2.00)	6.78 (1.96)	6.99 (1.61)	6.49 (1.89)		
4-month follow-up	6.98 (1.99)	7.00 (2.08)	6.24 (2.24)	6.33 (2.14)		
12-month follow-up	7.20 (2.06)	6.87 (1.91)	7.02 (1.48)	6.85 (2.02)		
MCRT response selection	N=56	N=49	N=53	N=39	0.44	0.28
Baseline	46.71 (35.00)	41.49 (42.83)	41.47 (32.29)	48.90 (35.18)		
4-month follow-up	66.39 (33.24)	55.15 (46.72)	51.64 (39.72)	55.50 (35.85)		
12-month follow-up	57.37 (32.41)	55.56 (48.87)	44.96 (29.54)	48.10 (32.09)		
MCRT inhibition	N=56	N=49	N=53	N=39	0.29	0.95
Baseline	139.8 (45.81)	145.8 (53.71)	143.9 (45.30)	126.00 (42.9)		
4-month follow-up	141.6 (51.52)	148.6 (54.00)	150.3 (50.97)	138.18 (41.76)		
12-month follow-up	136.4 (41.43)	144.9 (54.50)	147.9 (44.92)	133.73 (36.19)		
LDST	N=60	N=47	N=52	N=39	0.60	0.77
Baseline	47.27 (8.07)	44.42 (8.31)	46.88 (8.53)	46.09 (9.55)		
4-month follow-up	48.13 (8.80	44.65 (9.10)	47.02 (8.74)	47.00 (8.23)		
12-month follow-up	47.32 (7.77)	44.60 (8.66)	47.33 (9.12)	47.26 (9.15)		
CST simple speed	N=60	N=47	N=52	N=39	0.54	0.57
Baseline	25.23 (4.94)	26.46 (4.82)	25.47 (5.08)	26.25 (6.25)		
4-month follow-up	26.06 (4.84)	26.96 (5.74)	26.00 (5.20)	26.41 (6.11)		
12-month follow-up	26.25 (5.04)	28.24 (4.81)	26.34 (5.20)	26.85 (6.59)		
CST cognitive flexibility	N=60	N=47	N=52	N=39	0.04*	0.47
Baseline	12.83 (10.04)	15.50 (11.07)	13.31 (10.47)	14.68 (11.02)		
4-month follow-up	11.52 (9.41)	15.55 (9.60)	12.81 (10.67)	11.96 (10.12)		
12-month follow-up	10.38 (6.98)	12.81 (6.88)	13.22 (10.46)	10.53 (5.89)		
SCWT simple speed	N=59	N=47	N=52	N=39	<0.01*	0.19
Baseline	18.58 (2.30)	20.13 (3.37)	18.70 (2.45)	18.67 (2.22)		
4-month follow-up	18.77 (2.16)	20.49 (3.38)	19.05 (2.63)	19.38 (2.22)		
12-month follow-up	19.04 (2.47)	20.97 (3.32)	19.41 (2.58)	19.18 (2.43)		
SCWT inhibition	N=58	N=47	N=52	N=39	0.26	0.88
Baseline	23.74 (7.51)	28.17 (11.72)	24.68 (8.19)	26.81 (11.88)		
4-month follow-up	23.83 (6.85)	28.01 (10.52)	23.70 (7.23)	24.38 (10.89)		
12-month follow-up	24.29 (8.52)	27.39 (10.73)	24.77 (8.58)	24.49 (10.87)		
CFQ	N=57	N=47	N=53	N=39	0.31	0.24
Baseline	26.53 (11.59)	28.79 (12.92)	28.09 (11.08)	31.84 (11.29)		
4-month follow-up	28.18 (12.37)	29.95 (13.42)	28.99 (10.10)	30.71 (12.91)		
12-month follow-up	27.56 (12.91)	30.19 (14.73)	28.99 (13.23)	32.40 (12.97)		

intervention Group (p<.01). Finally, participants in the Training/No intervention Group were faster in terms of the simple speed measure of the SCWT compared with the

Intervention Group (p<.01), the No training/No intervention Group (p<.01) and the Control Group (p=.01). A group by time interaction was only found for the verbal learning variable of the VVLT (F(6,178)=2.196, p=.04). Post hoc analyses showed that both Training Groups showed an increase in the verbal learning variable from baseline to four-month follow-up measurements, whereas both No training Groups showed a decrease (see Figure 1). The difference between the Intervention Group and the No training/No intervention Group was significant (p=.04). No statistically significant main effects of group or significant group x time interactions were found in respect of all other cognitive measures as well as the CFQ.

Figure 1. *Means of the four groups at each measurement moment of the VVLT learning variable, adjusted for age,*



Repeating all analyses with exclusion or replacement of extreme values did yield comparable results. Also, all analyses were repeated with only the baseline measurements and the twelve-month follow-up measurements as six participants were not available for the four-month follow-up (and therefore not included in the original analyses). These analyses again yielded comparable results.

As for the extent to which participants in the Intervention Group used their computers, a significant difference between light and heavy computer users at baseline was only found for the interference variable of the SCWT (F(1,50)=4.607, p=.04). Participants who used their computers eight hours per week or more showed better interference scores than participants who used their computers less often. Repeated measures analyses revealed main effects of extent of computer use on the first trial of the VVLT (F(1,41)=10.125, p<.01), the summed score on the first three trials of the VVLT (F(1,41)=7.578, p<.01), the verbal learning capacity score of the VVLT (F(1,41)=5.425, p=.03) and the interference score on the SCWT (F(1.40)=6.617, p=.01). Participants who used their computers more often remembered more words on the first trial and on the summed score of the first three trials of the VVLT, and they needed less time to inhibit a habitual response in the SCWT. On the other hand, participants who used their computers less often showed higher verbal learning capacity in the VVLT. In other words the difference between the maximum number of immediately recalled words and the number of recalled words in the first trial of this group was higher than this difference in the group of heavy computer users in the Intervention Group.

An interaction effect between the extent of computer use and time was found for the summed score of the first three trials of the VVLT ($F(2,46)=3.533$, $p=.03$), showing that in the first four months of the intervention the summed score of heavy computer users decreased, whereas the score of light computer users increased ($p=.02$). The same was found for the delayed recall score in the VVLT ($F(2,46)=4.885$, $p=.01$). As regards this delayed recall score, the difference in change between light and heavy users was significant both between the four-month follow-up and the baseline measurements ($p=.02$) and also for the period between the twelve-month follow-up and the baseline measurements ($p=.01$). Finally, an interaction effect was found in the LDST ($F(2,46)=4.300$, $p=.02$). Between the four-month follow-up moment and the baseline measurements, heavy computer users showed an increase in the number of correctly substituted digits, whereas the light computer users showed a slight decrease ($p=.01$). Thereafter, between the four-month follow-up and the twelve-month follow-up moments, heavy computer users showed a decrease again, and the light computer users showed a slight increase ($p=.03$).

Discussion

The main question addressed in this study was whether an intervention for older adults - in which learning to use a personal computer and several Internet services followed by the subsequent use of these applications for one year - has an impact on measures of cognitive abilities. No effect of intervention was found on almost all of these measures. A difference in change over time between the groups was actually found in regard to only one cognitive measure, namely the learning variable of the VVLT. However, this interaction effect between group and time is quite random and does not appear to be caused by the intervention. There were also some main effects of group membership over time, but since no interactions with time were found, these effects cannot be attributed to the intervention.

We did find some interaction effects when the Intervention group was split into light and heavy computer users. Again, these effects appeared to be quite random and cannot be attributed to the extent of computer use. The main effects of group (light vs. heavy computer users) over time indicated that participants who used their computers eight hours per week or more showed better scores in trial one of the VVLT, the summed score of the VVLT, and the interference score of the SCWT. In other words participants with better verbal memory and better capacities to inhibit a habitual response (which is an attentional process) used their computers more extensively. On the other hand, participants who used their computers less than eight hours per week showed better verbal learning scores. This is probably a result of the fact that these participants remembered fewer words in the first trial of the VVLT and could thus improve more in the following trials compared with the heavy computer users. These results suggest that there is a relationship between computer use and cognitive abilities of older adults. However, as the differences between the light and heavy computer users do not change over time, the intervention did not have an impact on these cognitive abilities. Rather, it seems that older adults with better cognitive abilities tend to use a computer more extensively. This relationship between computer use and cognitive abilities was also reflected in the baseline comparison between participants who were interested in learning to use a personal computer and the Internet and participants with no such interest. Interested participants reported significantly fewer cognitive failures in the CFQ compared with participants who were not interested.

Besides the theoretical background of 'use it or lose it' and cognitive reserve, our hypothesis was based on earlier studies targeting cognitive functions of older adults that showed these functions improve as a result of training or intervention (Ball et al., 2002; Kliegl, Smith, & Baltes, 1989; Schaie & Willis, 1986; Stigsdotter & Backman, 1995). One major difference between these studies and our study that may have caused differences in findings concerns methodological issues. Many studies on cognitive training or interventions have methodological limitations, such as absence of control groups, small sample sizes, and thus low power, or flaws in the design or psychometric instruments (Brooks, Friedman, Pearman, Gray, & Yesavage, 1999). We tried to overcome these flaws by using a large sample size and a randomized design. Such a design has major advantages. For example, by including three control groups it was possible to study not just the effect of the intervention. We were also, at least theoretically, able to distinguish this effect from the effects of training and of participants' interest in computers and the Internet. It is possible that individuals who enrolled for the intervention differ from the individuals who were not interested in the intervention with respect to uncontrolled characteristics that could also have an effect on the outcome of this study (e.g. eagerness to learn, need for social contacts). Our design made it possible to conclude that finding no effect of the intervention was unrelated to potential confounders such as computer training or interest. Also, because of our design, we were able to control for social attention the participants of intervention studies are exposed to. Since the social interaction during the training sessions may have caused an effect that is not related to the actual intervention, we included a control group that received the same training as the Intervention Group did.

Our findings do not differ only from findings in studies targeting specific cognitive functions. There are also a few earlier studies showing that computer-based interventions similar to ours to some extent yielded positive effects on several psychosocial (Cody et al., 1999; Danowski & Sacks, 1980; McConatha et al., 1994; McConatha et al., 1995; Sherer, 1996; White et al., 2002) and cognitive measures (McConatha et al., 1994; McConatha et al., 1995). There are a number of differences between our study and the limited number of studies that did find effects of an intervention on cognitive ability measures. The first major difference is the study population. Both of the aforementioned studies included residents of care facilities, i.e. these individuals were not older adults living independently, whereas the participants in the present study were. It may be that our community dwelling participants had less to gain from the intervention. Because similar interventions do yield improvements of cognitive abilities in care facility residents, it is possible that individuals who have functional limitations could improve as a result of learning to use computers and the Internet. This is a research topic that could be explored in future studies. However, one should bear in mind that teaching complex skills, such as operating computers, to older individuals with cognitive limitations is probably very hard to accomplish.

A second major difference between our study and the earlier studies using computer-based interventions concerns the measures of cognitive ability. Both of the aforementioned studies (McConatha et al., 1994; McConatha et al., 1995) used a rather general measure of cognitive ability; the MMSE. In our study, more specific measures of cognitive functions that tend to decline with age were included. Because of these measures, we were able to study the impact of our intervention on many more aspects of cognitive functioning compared with the general measures used in previous research. Not only did these objective measures of cognitive abilities not change as a result of the intervention used in this study, we also did not find any effect of intervention on reported cognitive failures, which is a more subjective measure of cognitive functioning.

Apart from the advantages of the design and methodology described above, there are also some limitations in this study. A possible explanation for the lack of an effect of our intervention on cognitive ability is that the intervention insufficiently challenged the cognitive capacity of our participants. This explanation seems less plausible though. The participants in this intervention study had no prior experience with using computers and the Internet. According to the literature and the self-reports of our participants, older adults experience quite some difficulties in mastering computer skills and using computers and software applications. They are slower, make more errors and need more steps to reach their goals than individuals who are younger (e.g. Czaja & Sharit, 1997). Thus, learning to use computers and the Internet requires considerable cognitive effort from older adults. Another reason why it is not very sensible to assume that our intervention did not change the level of cognitive activity of the participants is the fact that the participants in the Intervention Group used their computers quite frequently, with an average of more than eight hours per week at the end of the intervention period. Also, they were encouraged to use the Internet by regular e-mail assignments of increasing difficulty throughout the intervention period. Overall, we do not believe that the intervention was insufficient in providing a true cognitive challenge for the participants.

Also, despite using a very strict study design, we were not able to account for some aspects that might have influenced the results. For instance, it cannot be ruled out that the follow-up period of our study was too short to detect differential changes in cognitive measures over time. A period of one year may be insufficient to detect differences in aging patterns, but does seem to be long enough to detect differential improvement, as is supported by other cognitive intervention studies with similar or shorter follow-up durations (e.g. Ball et al., 2002; Kliegl et al., 1989; Schaie & Willis, 1986; Stigsdotter & Backman, 1995). Another related issue that we are not able to resolve here, but that might be very relevant for the independent functioning of older adults, is the possibility that older individuals who have learned to use a computer and the Internet have better strategies to cope with cognitive limitations they might encounter in later life. As a personal computer and the Internet have several promising functions in this respect (e.g. providing reminders for people with memory problems), it is perfectly possible that older adults who master computer skills have more opportunities to compensate for future age-related limitations. Future studies could address this issue in more detail, although this type of research may not be very feasible because of problems such as high expenses and attrition.

In conclusion, we did not find an impact of learning to use computers and the Internet on a broad range of cognitive ability measures in a healthy group of older adults with no prior computer experience and living independently. The results of this study do not support the notion that stimulating the cognitive skills of older, community dwelling adults actually increases their cognitive abilities. However, the question of whether persons with more outspoken cognitive impairments have more to gain from such interventions if they are able to master the routines that are necessary for successful computer use remains unresolved. Finally, another question that remains interesting for future research is whether older adults who have received timely training to use computers and Internet services remain independent longer when functional limitations start to emerge.

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Chapter 5

The effects of computer training and Internet usage on autonomy, wellbeing and social network of older adults: A randomized controlled study

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Abstract

Quality of life of older adults may be improved by the use of computer or web-based services. A limited number of experimental studies on this topic have shown mixed results. A randomized controlled intervention study was carried out which aimed to examine the causal relationship between computer use and measures of perceived autonomy, everyday functioning, wellbeing and the nature and extent of the social network. A group of 191 participants were randomly assigned to an Intervention Group, a Training/No intervention group or a No training/No intervention Group. A fourth group consisted of 45 participants with no interest in computer use. Data were collected at baseline, after four and twelve months. The results showed that using computers and the Internet neither positively nor negatively influenced everyday functioning, wellbeing and mood, and the social network of healthy older individuals. Possibilities for future studies are discussed.

It is becoming increasingly difficult to function independently in modern Western society without the ability to use information technology (IT). This societal development is especially relevant for older adults as they have less experience and more problems with using IT (Czaja & Sharit, 1993; Czaja & Sharit, 1997; Kelley & Charness, 1995; Mead, Spaulding, Sit, Meyer, & Walker, 1997; Mead, Jamieson, Rousseau, Sit, & Rogers, 1996; Walker, Millians, & Worden, 1996).

Internet-based facilities may be of particular interest to older adults because the use of computers and the World Wide Web can offer specific opportunities for this age group. The benefits that are mentioned in the literature, based on theoretical assumptions, can be roughly divided into five separate categories. First, many researchers expect that the World Wide Web facilitates social interaction and communication (Czaja & Lee, 2001; Mead, Batsakes, Fisk, & Mykityshyn, 1999; Morrell, Mayhorn, & Bennett, 2000; Rogers & Fisk, 2000), and also creates opportunities for meeting new people (Czaja, 1996; White *et al.*, 2002). Second, using computers and the World Wide Web can provide means for entertainment and learning in the home (Czaja & Lee, 2001, 2003; Mead et al., 1999; White *et al.*, 1999). A third category of suggested possible benefits is related to the supporting role of the Internet for the autonomy of older adults, such as access to information services (Cody, Dunn, Hoppin, & Wendt, 1999; Czaja & Lee, 2003; White et al., 2002) and facilitation of routine tasks (e.g. banking and shopping) (Bouchard Ryan & Heaven, 1986; Czaja, Guerrier, Nair, & Landauer, 1993; Rogers & Fisk, 2000). The fourth category is concerned with benefits related to personal health. For instance, the World Wide Web may improve access to health services and care givers (Czaja, 1996; Czaja & Lee, 2001; Morrell et al., 2000; Rogers & Fisk, 2000; Stronge, Walker, & Rogers, 2001) and facilitate health care management (Czaja, 1997; Kelley & Charness, 1995). Finally, computers and the Internet could potentially improve general wellbeing and the quality of life. For example, it has been proposed that using a computer that is connected to the Internet provides mental stimulation and challenge to older adults (Jones & Bayen, 1998; McConatha, McConatha, & Dermigny, 1994; Mead et al., 1999). Also, it has been argued that computer use can decrease feelings of being left out of the modern society (Jones & Bayen, 1998; Lawhon, Ennis, & Lawhon, 1996) and improve self-esteem and satisfaction with life (Jones & Bayen, 1998; Lawhon et al., 1996; Mead et al., 1999; Sherer, 1996).

Although it seems obvious that computers and the Internet could improve the quality of life for older adults, only a few experimental studies have been done so far to substantiate these claims. In an early experiment (N=30), Danowski and Sacks (1980) introduced a computer terminal in an urban retirement hotel for a short period of three weeks, resulting in facilitation of communication with others. For instance, computer use provided topics of conversation with family and friends. However, this study was hampered by a large attrition rate of 57%, which may have biased the outcome.

McConatha, McConatha and Dermigny (1994) provided a small group (N=14) of long-term care residents with an on-line computer service, including e-mail facilities, an encyclopaedia, access to bulletin boards and other educational, recreational and information retrieval possibilities. After six months, users showed decreased depression ratings, increased activities of daily living (ADL) scores and improved cognitive function (Mini-Mental State Examination, MMSE). McConatha, McConatha, Deaner and Dermigny (1995) found comparable results with a larger sample (*N*=29) of nursing home residents who were randomly assigned to a computer training group or a control group. Participants in the training group used the same on-line computer service as had been used in the previous study and participants in the control group participated in regular nursing home recreational and educational activities. Again, participants in the computer training group improved with respect to satisfaction with their environment, feelings of control over their daily activities, and their sense of being in touch with the outside community.

In another study, Sherer (1996) placed personal computers with standard software applications (including a word processor, educational software and games) in a home for the aged and a day care centre for a randomized controlled experiment (*N*=40). After six months, the self-esteem and life satisfaction of the users improved in the exposed group compared with the Control Group. However, attrition bias may have occurred in this study as well, because only 35% of the randomized group completed the program.

Finally, White and colleagues (White et al., 1999) did a pilot study (*N*=23) showing that residents of a retirement community had decreased levels of loneliness after two weeks of computer and Internet training. However, this effect was no longer statistically significant after five months of subsequent computer use. Also, no differences between the computer group and a Control Group were found with respect to affect, depression and social support. A larger (*N*=100) replication of this pilot study showed no differences at all with respect to several aspects of the quality of life between the computer group and the control group as a result of 20 weeks of computer use (White et al., 2002).

Summarizing, the studies on the impact of computer use on the lives of older adults described above showed mixed results. In fact, these studies were not entirely suitable for answering questions about the impact of the Internet on the lives of healthy older adults because most of them used small groups recruited in nursing homes or other care facilities. It is, however, important to draw a more definitive conclusion because pursuing ways to improve wellbeing, perceived autonomy, social network and other aspects of the quality of life might contribute to prolonged independent everyday functioning into old age.

We conducted a randomized controlled intervention study in order to provide a methodologically more sound and powerful test of the hypothesis that learning to use computers and the Internet is beneficial to the quality of life of older adults. It involved a large group of participants (*N* = 236) who were randomly assigned to conditions with or without such a cognitive challenge. This number of participants was necessary to yield sufficient power to find a medium effect size of intervention because the participants were assigned to one of four conditions. As a result of this random allocation to four conditions, we were able to analyze the effects of intervention, training and interest in the intervention separately. This distinction is relevant for the qualification of effects and it has not been made in previous studies. To assess the effect of the intervention, a number of questionnaires measuring a wide array of domains of perceived autonomy, wellbeing and social network were administrated at baseline, and four and twelve months after the start of the intervention.

Methods

For information about the participants and the procedure of the intervention study, see Chapter 3.

Measures

The outcome variables of this study were obtained from questionnaire information. These measures covered the domains of autonomous everyday functioning, wellbeing and mood, and social network as well as some demographic items (level of education and income as a measure of social economic status).

Autonomous, everyday functioning. Physical functioning was measured using the number of problems with instrumental activities of daily living (IADL) as well as the physical component of the SF-36, a 36-item questionnaire on general health and the quality of life (Ware, Snow, Kosinski, & Gandek, 1993). Psychological functioning was measured using the mental component of the SF-36.

Wellbeing. General wellbeing was measured using the loneliness questionnaire (LQ, (De Jong-Gierveld & Kamphuis, 1986)) and the satisfaction with life scale (SWLS) (Pavot, Diener, Randall Colvin, & Sandvik, 1991). Measures of mood were provided by three subscales of the Symptom Check List (SCL) 90 (Arrindell & Ettema, 1986): depression, anxiety and sleep complaints. Finally a Belief in External Control scale (Andriessen, 1972) was used to measure locus of control (internal or external) and the Mastery scale (Pearlin & Schooler, 1978) was used to ask participants about their perceived level of control over life.

Social network. Four items were included to measure the nature and frequency of participants' social networks. The first item concerned the number of people participants know they can rely on for help with whom they share private matters (Stevens, Kaplan, Ponds, Diederiks, & Jolles, 1999). The second item concerned the number of people participants know they can rely on for help, but with whom they do not discuss private matters. Both questions were followed by an indication of the frequency participants contacted one of these people.

Other outcome variables. Apart from the measures referred to above, a number of other outcome variables relevant to the quality of life were included. First, two subscales of the Eysenck Personality Questionnaire (EPQ), (Eysenck & Eysenck, 1975) were included: neuroticism and extraversion. Second, participants were asked to estimate how many hours per week they engage in several activities (watching television, reading, participating in clubs, physically active sports, light sports, mentally active sports, grocery shopping, cooking and personal care, hobbies, learning new things and meeting with friends). Also, participants were asked if they considered themselves an active person and how active they considered themselves compared with their age peers. A final item was included to ask whether participants engage in volunteer work.

Measures of computer use. In order to account for the extent to which individuals in the Intervention Group actually used their computer and the Internet, participants in this group were asked at both the four-month and at the twelve-month follow-up moments to indicate how many hours per week they had used the computer and the Internet in the period prior to answering the questions.

Statistical analyses

Statistical analyses were performed with the SPSS v11.0 program series for Apple Macintosh. ANOVAs and Chi-square tests were conducted on all dependent variables, the MMSE score and a number of demographical characteristics (age, sex, education, and income as a measure of social economic status) to study differences between the four groups at baseline. A General Linear Model (GLM) with repeated measures analysis of variance was used to study the effect of the intervention. Analyses were conducted with group as between-subject variable (four levels: Intervention, Training/No intervention, No training/No intervention and Control Group) and time as within-subject variable (three levels: second baseline, four-month follow-up and twelve-months follow-up). Contrasts were defined to compare changes in performance over time (between the three measurements) of the four groups. Age, level of education, income and sex were used as covariates. We were especially interested in the interaction of time and group, as this interaction shows whether the groups differed from one another with respect to changes over time in the dependent variables. Friedman tests were conducted for dependent variables that were not interval or ratio scaled (both frequency questions of social network and the items regarding whether participants considered themselves active persons and whether they considered themselves more or less active than others). Some variables were dichotomized (IADL, hours per week spent on club memberships, physically active sports, mentally demanding sports, hobbies, acquiring new skills, and participation in volunteer organizations) and were analyzed with Cochran's Q test.

All analyses were repeated with only the individuals in the Intervention Group in order to account for the extent of computer use. In these analyses the between-subject variable, extent of computer use, had two levels: light and heavy. This variable was calculated by using a median split method on the number of hours per week participants indicated using their computer at the twelve-month follow-up moment. In this case the median was 7.5 hours, so participants who reported using their computer 7 hours per week or less were labelled 'light users' and participants who reported using their computer 8 hours per week or more were labelled 'heavy users'.

All variables that were included in the analyses were first checked for normal distributions, missing values and outliers. No data transformation procedures were considered necessary for the analyses. All analyses were done with and without individual cases with extreme values and finally with replacement of extreme values by the highest values that were not labelled as extreme values (extreme values were defined as more than three times the interquartile range above the 75th or below the 25th percentiles). All statistical analyses were performed with $p=.05$ as significance level.

Results

Baseline comparisons

At baseline the four groups did not differ with respect to age, sex, level of education and monthly income. Baseline comparisons of the outcome variables showed differences in belief in external control ($F(3,226)=3.13$, $p=.03$) and in the number of hours participants spent on light sports ($F(3,225)=2.73$, $p=.045$). Post hoc analyses showed no differences between the four groups as regards belief in external control and showed that participants in the Training/No intervention Group spent more time on light sports ($p=.03$). This difference was not found when participants who dropped out at a later moment were left out of the analyses.

Differences between interested and not interested participants were found for the anxiety scale of the SCL-90 ($F(1,230)=6.97$, $p<.01$): the former showed less anxiety. This difference remained when participants who dropped out were left out of the analyses.

Baseline comparisons of participants who dropped out of the study at some point ($n=38$) with participants who completed all test administrations ($n=198$) showed differences in level of education ($F(1, 229)=4.13$, $p=.04$), with lower levels for participants who dropped out, belief in external control ($F(1,229)=5.69$, $p=.02$), also with lower levels for participants who dropped out, and the number of hours spent on grocery shopping, cooking and personal care ($F(1,228)=5.30$, $p=.02$): participants who dropped out spent more time on these activities.

Computer use

Participants reported using their computer an average of 8.7 hours per week ($SD=5.8$) at the four-month follow-up and 8.3 hours per week ($SD=6.2$) at the twelve-month follow-up. The difference between these moments was not statistically significant. Of the time participants used their computers, they spent 7.0 hours per week on the Internet ($SD=5.6$) at the four-month follow-up moment, and 6.5 hours per week ($SD=5.6$) at the twelve-month follow-up. Again, the difference between the two moments of measurement was not statistically significant.

Effects of the intervention

Results of the repeated measures analyses are shown in Table 1. No significant group by time interactions were found. Differences between the groups in changes over time were found in the frequency with which participants contacted people they could rely on for help. At the four and twelve-month follow-up, participants in the Training/No intervention Group reported seeing people they discuss their private matters with less often than at baseline ($\chi^2(2, n=44)=7.93$, $p=.02$). The same was true for the number of people participants did not discuss private matters with ($\chi^2(2, n=39)=9.65$, $p=.01$). Significant changes were not found for the other groups. The number of people participants could rely on did not change for any of the groups. Differences between the groups in changes over time were also found for the time spent on watching television ($F(3,185)=2.59$, $p=.02$).

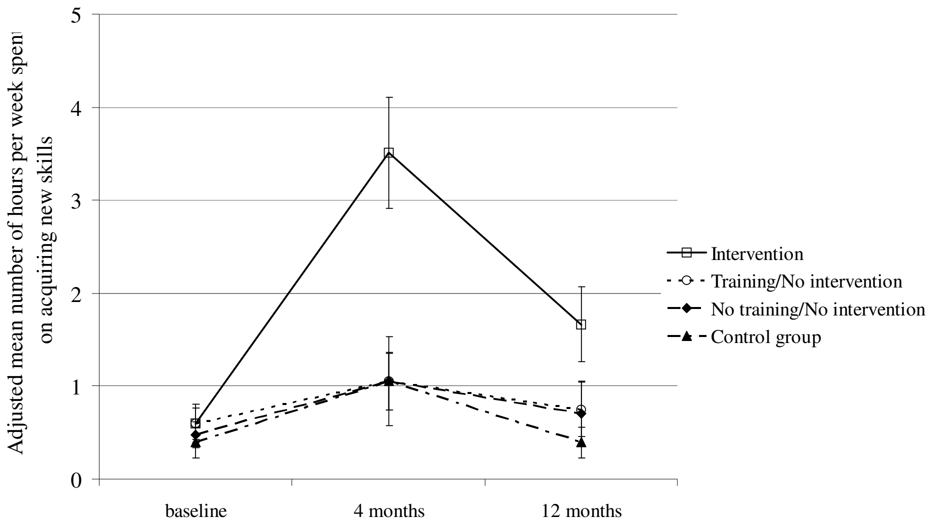
Table 1 *Means, standard deviations and group * time interactions for the outcome variables*

	Training/ Intervention	Training/ No intervention	No training/ No intervention	Control Group	Group*time effect p-value
Physical functioning SF36	N=57	N=46	N=52	N=39	0.14
Baseline	51.71 (6.93)	52.05 (6.10)	49.42 (8.39)	50.08 (8.39)	
4-month follow-up	50.52 (7.98)	50.05 (8.14)	48.64 (7.27)	48.94 (8.66)	
12-month follow-up	49.08 (8.16)	48.22 (8.84)	48.25 (9.50)	49.57 (8.35)	
Mental functioning SF36	N=57	N=45	N=52	N=39	0.10
Baseline	54.00 (8.39)	54.31 (7.25)	53.70 (6.61)	53.54 (8.02)	
4-month follow-up	51.95 (9.49)	54.34 (8.17)	54.29 (6.95)	54.11 (8.46)	
12-month follow-up	52.97 (7.98)	53.69 (8.83)	52.21 (8.93)	52.07 (10.51)	
Loneliness Questionnaire	N=57	N=45	N=50	N=38	0.84
Baseline	34.71 (3.64)	34.26 (3.74)	33.69 (3.47)	34.74 (3.97)	
4-month follow-up	34.18 (3.54)	34.67 (3.66)	33.28 (3.70)	34.32 (3.88)	
12-month follow-up	34.74 (2.97)	34.70 (4.06)	33.70 (2.84)	34.27 (2.69)	
Satisfaction With Life	N=56	N=45	N=49	N=38	0.90
Baseline	25.84 (4.77)	24.96 (4.88)	25.22 (4.59)	25.89 (4.77)	
4-month follow-up	25.48 (4.83)	24.57 (5.12)	24.33 (5.09)	25.55 (5.35)	
12-month follow-up	25.34 (4.60)	25.04 (4.86)	25.35 (4.61)	25.92 (5.06)	
SCL Depression	N=55	N=45	N=50	N=38	0.56
Baseline	21.21 (5.74)	21.64 (6.04)	21.31 (5.20)	22.51 (5.71)	
4-month follow-up	22.92 (8.31)	21.99 (8.41)	21.95 (6.46)	22.77 (7.58)	
12-month follow-up	22.61 (8.13)	22.48 (8.15)	20.85 (5.04)	23.16 (8.01)	
SCL Anxiety	N=57	N=45	N=50	N=38	0.13
Baseline	11.98 (2.97)	12.11 (2.67)	12.18 (2.75)	13.40 (3.70)	
4-month follow-up	12.98 (4.37)	12.66 (4.46)	12.36 (2.75)	12.82 (3.39)	
12-month follow-up	12.23 (3.25)	12.47 (5.23)	12.07 (2.43)	13.53 (3.59)	
SCL Sleep complaints	N=57	N=45	N=50	N=38	0.89
Baseline	5.21 (2.57)	5.67 (2.87)	5.86 (2.82)	6.32 (2.90)	
4-month follow-up	5.63 (2.69)	5.37 (2.65)	6.04 (3.08)	6.26 (2.99)	
12-month follow-up	5.28 (2.38)	5.51 (2.09)	5.86 (3.06)	6.37 (2.97)	
Belief in external control	N=56	N=45	N=50	N=38	0.92
Baseline	36.44 (6.43)	34.20 (7.49)	34.41 (6.91)	37.11 (6.99)	
4-month follow-up	36.15 (7.66)	33.14 (8.00)	33.72 (7.24)	36.87 (7.60)	
12-month follow-up	36.39 (7.22)	33.15 (7.85)	34.33 (7.71)	36.32 (8.03)	
Mastery	N=56	N=45	N=50	N=38	0.13
Baseline	24.69 (3.62)	23.72 (4.42)	24.34 (3.43)	25.00 (3.27)	
4-month follow-up	24.61 (3.50)	23.70 (3.79)	23.52 (3.44)	25.24 (3.72)	
12-month follow-up	24.83 (3.81)	24.12 (3.90)	24.00 (3.53)	24.00 (4.30)	
EPQ Neuroticism	N=50	N=40	N=43	N=35	0.22
Baseline	2.48 (2.43)	2.53 (2.61)	2.77 (2.86)	2.86 (2.79)	
4-month follow-up	2.74 (2.74)	2.60 (2.91)	2.19 (2.51)	2.60 (2.76)	
12-month follow-up	2.86 (2.71)	2.35 (2.94)	2.44 (2.76)	2.69 (2.76)	
EPQ Extraversion	N=47	N=39	N=38	N=32	0.24
Baseline	6.32 (2.22)	6.56 (2.36)	6.03 (2.24)	5.53 (2.24)	
4-month follow-up	6.06 (2.52)	6.28 (2.71)	6.16 (1.97)	6.03 (2.39)	
12-month follow-up	5.94 (2.51)	6.18 (2.62)	6.05 (2.39)	5.59 (2.20)	
Private matters	N=51	N=40	N=43	N=37	0.92
Baseline	6.35 (4.77)	5.49 (4.51)	6.28 (5.00)	5.19 (3.95)	
4-month follow-up	5.82 (4.30)	5.29 (3.61)	6.49 (4.82)	4.97 (3.72)	
12-month follow-up	6.37 (4.11)	5.17 (4.15)	5.86 (3.77)	5.51 (3.62)	
No private matters	N=49	N=31	N=38	N=32	0.45
Baseline	4.39 (4.39)	2.63 (2.17)	3.76 (4.69)	2.97 (2.96)	
4-month follow-up	4.35 (4.34)	2.69 (2.35)	4.42 (4.25)	3.19 (2.51)	
12-month follow-up	4.61 (6.19)	4.75 (4.70)	3.87 (2.72)	4.00 (3.65)	

Note *SF36 = Short Form 36, SCL = Symptom Check List, EPQ = Eysenck Personality Questionnaire, "Private matters" = the number of people participants contacted with whom they discuss private matters, "No private matters" = the number of people participants contacted with whom they do not discuss private matters.*

However, post hoc analysis showed that none of the groups differed from one another. Changes within groups were also found in the Intervention Group with regard to the time spent on learning new things ($Q(2, n=55)=26.18, p<.01$). Participants in this group indicated spending more time on learning new things at the four-month follow-up measurement than at baseline (see Figure 1). Also, scores relating to whether participants consider themselves an active person changed for the No training/No intervention Group ($\chi^2(2, n=50)=17.27, p<.01$). Participants in this group considered themselves less active at the follow-up measurements than at baseline. Finally, time spent on volunteer work changed for the Training/No intervention Group ($\chi^2(2, n=46)=8.36, p=.02$). These participants spent less time on volunteer work at the four-month follow-up moment than at baseline and at the twelve-month follow-up. Repeating all analyses with exclusion or replacement of extreme values did not yield different results.

Figure 1 *Mean (SEM) number of hours spent on acquiring new skills for each group at the three moments of measurement adjusted for age, sex and level of education*



No significant differences between light and heavy computer users were found at baseline. Repeated measures analyses revealed an interaction between extent of computer use and time for the Mastery questionnaire (F(2,48)=3.31, p=.04), showing that between the baseline measurement and the twelve-month follow-up moment heavy computer users showed an increase on the Mastery scale, while light computers users showed a decrease (p=.01). Post hoc analyses (paired t-tests with Bonferroni correction) revealed that the increase in the Mastery score between baseline and the twelve-month follow-up of the heavy computer users was statistically significant after Bonferroni correction (t(23)=-2.27, p=-.03) while the decrease of the light computer users was not significant. Significant changes over time were found for the frequency of meeting with people participants share private matters with (light computer users showed an increase in this frequency between baseline and the four-month follow-up and a decrease again after the four-month follow-up ($\chi 2(2, n=24)=8.23$, $p=.01$)), for the time participants spent on hobbies (heavy computer users showed an increase over all time intervals on this measure ($Q(2, n=24)=6.33$, $p=.04$)) and for the time participants spent on acquiring new skills (light computer users showed an increase between baseline and the four-month follow-up and decreased again after the four-month follow-up to the baseline level ($Q(2, n=24)=16,55$, $p<.01$)). Heavy computer users also showed an increase between baseline and the four-month follow-up but only a slight decrease after the four-month follow-up ($Q(2,24)=11.41$, $p<.01$)).

Discussion

The main question of this study was whether an intervention for older adults, which involved learning to use a personal computer and several Internet services followed by the subsequent use of these applications for one year, has an impact on measures of autonomous everyday functioning, wellbeing and social network. Earlier studies that focused on the same question used methodologically less accurate designs and yielded inconsistent results. We therefore used a rigorously controlled randomized design to account for these drawbacks and to provide an unambiguous answer. No clear-cut effect of intervention was found for the majority of these measures. The differences that were found were quite random and did not appear to be caused by the intervention. The only exception is the fact that participants in the Intervention Group indicated spending more time on learning new things, which was to be expected as these participants learned to use a personal computer and the Internet.

We did find some differences in changes over time between participants in the Intervention Group who used their computers 8 hours per week or more (heavy computer use) and participants who used their computers less than 8 hours per week (light computer use). In this group, heavy users showed an increase in mastery, while light computer users did not. That is to say, participants who used their computers more often felt more in control of their lives as a result of their frequent computer use. Also we found that heavy computer users in the Intervention Group gradually reported spending more time on their hobbies during the study, which is probably due to the fact that they started using a computer, which they considered one of their hobbies. Both heavy and light computer users reported spending more time on acquiring new skills at the four-month follow-up than at baseline. As was anticipated, after the four-month follow-up the time spent on new skills dropped to baseline level for participants who did not use their computers very often, while this time dropped only slightly for the participants who used their computers more frequently. A final variable in which we found a change over time was the frequency with which participants reported contacting people with whom they discussed private matters. For the heavy computer users this frequency was stable during the study, for light computer users the frequency temporarily increased at the time of the four-month follow-up. These differences between heavy and light computer users appear rather unsystematic and may be a chance finding.

In short, the fact that we found no differences between the Intervention Group and the other groups over time does not confirm the hypothesis that learning to use the Internet would have a positive effect on these measures. These findings do not correspond to results of studies that used to some extent similar interventions (Cody et al., 1999; McConatha et al., 1994; McConatha et al., 1995; Sherer, 1996; White et al., 1999). However, these differences in findings may be attributable to several factors that are discussed below.

The first and most important difference concerns methodological issues. Almost without exception, the earlier studies used far fewer participants, less systematic designs (e.g. no control groups), and a number of them reported quite dramatic attrition numbers. Also, unlike in the present study, in most studies no care was taken to control for social contact in the Intervention Group as a result of training or the use of a personal computer in a shared environment (McConatha et al., 1995). This social contact may have caused contamination of the intervention effect. In our study, this effect was accounted for by including the Training/No intervention Group, which received the same training as the Intervention Group did. Following the same line of reasoning, the question is often raised as to whether an effect of computer usage, or any other intervention, should be attributed to the usage itself or to uncontrolled characteristics of the individuals who choose to learn to use computers (e.g. a need for stimulation or social engagement, or an eagerness to learn). In this study, the inclusion of a group of people who enrolled for the intervention, but who were eliminated from the training and the intervention by randomization (the No training/No intervention Group), made it possible to study the effect of our intervention separately from these characteristics.

Second, the current study was primarily focused on healthy older adults who live independently, while in most of the aforementioned intervention studies participants were recruited from residents in care facilities. Our study population may have been a particularly fit group of older adults who are not, or at least not yet, limited in their physical, mental and social capabilities. The lack of effect of this intervention may therefore be due to a restricted range in functional limitation in this group, with only limited gain to be expected from the intervention. Possibly, as was the case in the studies that did find an effect of intervention, the intervention in this study might be more effective when presented to older adults with functional limitations, such as nursing home residents.

The fact that our sample size was adequate and that rigorous experimental control was used reinforces our conclusion that no effect of computer and Internet usage on health and wellbeing is to be expected among community dwelling older adults. Regarding the potential benefits of using computers and the Internet that were mentioned earlier, we have found no evidence for facilitation of social interaction, independence, health and satisfaction with life. However, some anticipated benefits of the Internet are hard to quantify and measure with instruments that are available today. For example, being able to use a computer and the Internet could make older adults feel more competent to keep themselves up to date, and decrease feelings of being left out. Also, their feelings of involvement in the modern, IT-driven experiences of their children and grandchildren may increase. However, the changes that are brought about by this ability are probably too subtle or may become manifest in areas different from the areas we focussed on in this study.

One aspect that we have not been able to account for is a possible difference between individuals who take the initiative themselves to change their lifestyle and individuals who are only inclined to make such a change when a special opportunity is offered to them, for example by participating in the current study. In other words, providing an intervention to research participants might not yield the same results as a similar activity would in a group of people who take action to learn to use a computer on their own. However, this is an assumption that has yet to be experimentally tested.

A final aspect of this study that could have influenced the results is the duration of exposure to the intervention. It could be argued that one year is too short to cause any substantial changes. On the other hand, if changes in everyday performance and wellbeing cannot be detected over a one-year period, we expect that such changes are probably also not likely to occur after a longer period. Nevertheless, there is a possibility that the participants who took up the challenge of mastering the personal computer, and who have experienced the possible opportunities of the Internet for remaining independent and in touch with society, will cope more effectively with age-related challenges to autonomy not yet prevalent in our study sample. Studying the effects of Internet usage for more than one year will be difficult because of the increasing number of older persons who have started using computers for their personal use. This makes another randomized controlled trial in this area in the future rather unlikely.

Summing up, in spite of scanty reports of a positive influence in earlier studies, we did not find consistent evidence for an impact, either positive or negative, of learning to use computers and the Internet on the everyday functioning, wellbeing, mood, social network, personality or activity levels of healthy older adults. This implies that in order to improve the quality of life of healthy older adults, the benefits of computer and Internet-related activities for personal use are limited. In our opinion, future research efforts should be aimed at identifying populations that may be more sensitive to Internet-based intervention. The question remains as to whether older adults who have received timely training to use computers and Internet services for a while are able to profit from this skill at the moment they are faced with functional limitations.

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Chapter 6

The efficiency of using everyday technological devices by older adults: The role of cognitive functions

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Abstract

Older adults experience more problems than younger people when using everyday technological devices. One potential cause of these difficulties is age-related cognitive decline. To test the role of cognitive abilities in performing technological tasks, we designed the Technological Transfer Test (TTT). This new and ecologically valid test consists of eight technological tasks common in modern life, such as operating a CD player and a microwave oven. The TTT and a comprehensive battery of cognitive tests were administered to 236 healthy older adults (aged 64 to 75) on two separate occasions. The results demonstrated that performance time for five out of eight of the technological tasks was predicted by cognitive abilities. Speed of information processing and cognitive flexibility were the most predictive cognitive abilities in regard to TTT performance. The results imply that age-related cognitive decline can have a profound effect on the interaction between older adults and technological appliances.

An increasing number of everyday tasks and routines in modern life require their users to deal with (information) technology. Examples of everyday technological devices for which non-technological alternatives are barely available anymore are automatic teller machines (ATM), train ticket vending machines and thermostats. Older adults often experience difficulties when using modern technology. For example, it has been shown in several studies that when learning to use a computer, older adults take longer to master the system, make more errors and require more help than younger people do (Charness, Bosman, Kelley, & Mottram, 1996; Czaja & Sharit, 1993; Kelley & Charness, 1995). Furthermore, it has been reported that older adults experience problems when using more common everyday systems, such as ATMs (Rogers, Gilbert, & Fraser Cabrera, 1997).

The difficulties older adults encounter when using such technologies may eventually compromise an independent lifestyle, which is a primary goal of many older individuals (Rogers & Fisk, 2000; Willis, 1996). Everyday tasks that are essential to independent functioning, but which have become more and more technology-driven, may become too difficult for older adults to perform autonomously. It is therefore important to evaluate and improve the usability of everyday technological systems to accommodate the needs of older users.

An essential step in the process of enhancing this usability is to study the causes underlying the problems older adults face when they use technology. One potential cause is age-related cognitive change (Freudenthal, 2001; Kelley & Charness, 1995; Rogers & Fisk, 2000). Cognitive abilities tend to decline with age (e.g. Craik & Salthouse, 2000; Houx & Jolles, 1993a; van der Elst, van Boxtel, van Breukelen, & Jolles, 2005b; van Hooren *et al., in press*) and many of these skills seem to be essential in using complex technological systems. For instance, speed of information processing may be important when using many public technological devices, such as ticket vending machines, as these devices tend to 'time out' after a certain period of insufficient input. Also psychomotor processes, such as response selection, are probably important when using technological systems because often multiple options are available at the same time and the user has to decide on the correct option and has to make the appropriate response. Memory ability may be important in task performance, e.g. in remembering options or system output at a later stage (short term or working memory) or to retrieve factual or procedural information from long-term memory. Finally, the ability to switch between several concepts or cognitive processes appears to be vital in many technological tasks. An example is switching between remembering a PIN code and selecting the appropriate buttons on an ATM. By increasing knowledge on the exact cognitive abilities that underlie problems with technology, it may be possible to adjust new technologies to meet older users' capacities and thereby improve the efficiency of their use.

At present, an ecologically valid test of technological efficiency does not seem to exist. Many studies on age-related differences in dealing with technology use very specific, mostly computer-based technological applications (e.g. several computer tasks (Czaja & Sharit, 1993; Mead, Jamieson, Rousseau, Sit, & Rogers, 1996), automatic teller machines (Mead & Fisk, 1998) or simulated unfamiliar complex devices (Freudenthal, 2001)). However, these applications are too specific to study technological abilities that are of importance to everyday independent functioning. In order to study the role of cognitive abilities in using everyday technological devices, we designed a new test that consists of several technological tasks common in daily life. See the Methods section for a detailed description of the test. This test enabled us to measure older users' efficiency in performing everyday tasks involving technological devices. More specifically, the present test was developed for a randomized intervention study of the impact of computer training and Internet use on the autonomy of older adults. Participants in this study who were assigned to the Intervention Group received a computer with a high-speed Internet connection at their homes for a one-year period. The technological ability test was intended to measure whether learning to use a personal computer and the Internet also has a more general effect on the use of other (everyday) technologies (Slegers, van Boxtel, & Jolles, submitted). This test was labelled the 'Technological Transfer Test', or TTT.

By simultaneously measuring cognitive abilities together with the TTT in the present study, it was possible to examine the relationship between actual technological skills and cognitive abilities in a large group of older adults. To our knowledge, this has not been done before in relation to real life technological tasks. It was hypothesized that cognitive abilities known to decline with age (more specifically verbal memory, information processing speed, cognitive flexibility and psychomotor processes) determine older adults' efficiency in performing common technological tasks. The cognitive tests that were used in this study tap into a broad range of cognitive abilities and were used in the core battery of a longitudinal study on determinants of cognitive aging (Jolles, Houx, van Boxtel, & Ponds, 1995). Other factors that could possibly influence technological efficiency that were controlled for in this study were visual acuity (as some of the devices used contained rather small buttons and visual information), basic motor speed (as participants who have very high motor speed will probably also be faster in operating the devices), and the past experience of participants with similar devices. Finally, since there were both participants with and without an interest in information technology (IT), and participants with and without exposure to an intervention (in which they used a computer and the Internet for twelve months), we also controlled for interest in IT and exposure to the intervention.

The research topic of this paper is very relevant with respect to autonomous functioning and the quality of life of older adults. To our knowledge, the relationship between cognitive functions and using technology has not been extensively studied before. Therefore, the present study of a large group of older people may provide knowledge with important implications with respect to the application of technology in the lives of older adults.

Methods

For information about the participants and the procedure of the intervention study, see Chapter 3. For the purpose of this paper, baseline and twelve-month follow-up data were used.

Measures

Technological ability. To measure technological ability, the Technological Transfer Test was used. The TTT was administered twice during the study, once at baseline and once at the end of the study after twelve months. On both occasions, participants had to successfully operate four technological devices that are common in modern daily life (for an overview of the devices, see Table 1).

The technological devices in the TTT were chosen to represent a broad range of technological tasks with which older adults may regularly be confronted in everyday life. The eight tests were balanced over the two test occasions with respect to expected familiarity and difficulty with the particular devices in order to avoid the assignment of similar tasks on both occasions. By doing so, we were able to design two parallel versions of the TTT. Since many of the specific devices that were used in this test were unfamiliar to the participants, learning effects are to be expected in the case of repetition of the same task. We therefore chose to use different tasks in each test.

At each test administration, two of the tasks consisted of real-life consumer devices. The other two were common public technological devices, simulated on a computer that could be operated with a touch screen interface. These devices were simulated because they are for public use only and are not commercially available.

Participants received a brief instruction sheet with a clear assignment (see Table 1) for each device. The instruction sheet for the real-life devices also contained brief directions for use, adapted from the original instructions supplied with the devices. Participants were instructed that they could, but did not have to, use these instructions. Overall, participants were instructed to complete the assignments as fast and as accurately as possible. The experimenter was not allowed to assist the participants in any way. If a participant was convinced the task had been completed when this was not the case, the participant was informed that the task had not been completed yet and was encouraged to try again.

We used the performance time to measure the efficiency of completing the aforementioned assignments for all types of devices. The number of errors that participants made was also considered for the simulated devices, because a log file of participants' actions was available for these devices. As the use of the instructions provided with the assignment for the real-life devices was not obligatory, the time to read the instruction sheet (including the directions for use) was included in the general performance time. This was done in order to take into account whether participants needed to use the directions or not. As regards the simulated devices, no directions for use were provided, so in order to avoid measuring differences in reading speed, participants were allowed to read the instructions before the task was started.

Performance time was used as the primary outcome measure because it is a simple but complete measure of efficiency. This measure not only gives information about the time participants needed to understand and operate the devices, but also about the time that was spent on recovery from mistakes. Finally, a total general score for the four tasks was computed in both test administrations. As the tasks were quite different with respect to the

Table 1 *Overview of the technological transfer test devices and assignments*

Device	Type	Assignment
Baseline		
CD player	real	"Play song number four from this CD."
Telephone	real	"Program this phone number in the memory of this phone."
Automatic teller machine	simulated	"Withdraw the maximum amount of money from this bank account."
Train ticket vending machine	simulated	"Buy a return ticket to the city of Eindhoven."
12-month follow-up		
Microwave oven	real	"Heat up this glass of water for 60 seconds."
Alarm clock	real	"Set the alarm clock for 7:15 am. tomorrow."
Smartcard charger	simulated	"Charge this smartcard with 150 Euros."
Telephone voice menu	simulated	"Arrange travel insurance for a holiday in Spain."

time needed to perform the assignments, the original scores for each task were transformed to z scores and summed for this general score in order to be able to compare the four tasks in each test administration.

Level of education. Level of education was measured on an eight-point scale as used by Statistics Netherlands (De Bie, 1987). The scale ranges from primary education to higher vocational training and university degree.

Visual acuity. Visual acuity was measured with Landolt-C optotype chart, at a distance of five meters, under standard luminescence and with corrected vision (Hollwich, 1989).

Basic motor speed. A continuous tapping test was included to measure basic motor speed. In this test, participants were required to press the button of an electronic counting device with the index finger of their preferred hand at maximum frequency for 30 seconds (Brand & Jolles, 1987).

Frequency of using TTT devices. Participants were asked to rate on a five-point scale how often they used each of the eight technological devices that were included in the TTT. The scale ranged from 'never' to 'at least once a week'.

General cognitive speed. The Letter-Digit Substitution Test (LDST) (van der Elst, van Boxtel, van Breukelen, & Jolles, in press) is a modification of the Symbol-Digits Modalities Test (Lezak, 1995) and is used to measure the general speed of information processing. A code is provided at the top of a sheet of paper that couples the numbers 1 to 9 with random letters. Participants were asked to fill in as many corresponding numbers as possible in 90 seconds in boxes on the rest of the sheet that contained only letters.

Verbal memory. The Visual Verbal Learning Test (VVLT) (Brand & Jolles, 1985; van der Elst, van Boxtel, van Breukelen, & Jolles, 2005a) was used to measure verbal memory and verbal learning. In this test, fifteen monosyllabic, low-associative words are presented one after another on a computer screen. After the presentation, participants were asked to recall as many words as possible without any time or order constraint (immediate recall). This procedure was repeated five times with the same list of words. Twenty minutes after the recall of the fifth trial, the participants were once more asked to recall as many words as possible (delayed recall). The score in the first trial of the immediate recall and the delayed recall score were used for this study as indications of short-term and long-term memory respectively.

Cognitive flexibility. The Concept Shifting Test (CST, Vink & Jolles, 1985) is modified from the Trail Making Test (Reitan, 1958; Vink & Jolles, 1985) and is used to measure cognitive flexibility. This test consists of three sheets of paper with 16 small circles that are grouped in a larger circle. On the first sheet, numbers appear in the small circles in a fixed random order. Participants were asked to cross out these numbers in the right order as fast as possible. Instructions for the second sheet were identical to those for the first sheet, except that on this sheet letters appear in the circles. On the third sheet, participants had to alternate between numbers and letters. The time needed to complete each of the sheets was recorded. The difference between the score for the third sheet and the mean of the scores for the first and second sheets was used as an estimate of the slowing due to the shifting between two concepts (numbers and letters), i.e. cognitive flexibility.

Psychomotor speed. The Motor Choice Reaction Time test (MCRT) (Houx & Jolles, 1993b) was included to measure psychomotor speed. This test is conducted with a six-button panel, containing one red button and five white buttons, laid out in a semicircle around the red button. The participants were asked to hold down the red button with the index finger of the preferred hand as long as no white button was lit. As soon as one of the white buttons was lit, the participants were to release the red button and then press the lit button (or a button adjacent to it) as quickly as possible. After this, the red button had to be held down again. The MCRT involved three conditions. In the first condition (simple reaction time), only the upper white button was lit. In the second condition (choice reaction time), one of the three upper buttons was lit. In the third condition (incompatible choice reaction time), one of the three upper buttons was lit, however, the button immediately to the right of the lit button was to be pressed. Two variables were of interest for this study. Firstly, the difference between the median response times of the second and the first conditions was used as an indication of response selection. Secondly, a measure of inhibition of a prepotent response (Kornblum, Hasbroucq, & Osman, 1990) was provided by the difference between the third and the second conditions.

Statistical analyses

Reliability. In order to study the reliability of the newly developed TTT, reliability analyses and factor analyses were conducted on the performance times. To test the consistency between the four tasks of each of the two administrations, Cronbach's alphas and the correlations between each of the four tasks were calculated. Factor analyses were performed to test whether the four tasks of each test administration loaded on the same factor.

Regression analyses. The performance time for each of the TTT tasks and the general scores of both tests were predicted using multiple hierarchical regression analysis. Since the performance time data of the train ticket vending machine task were not normally distributed, a log-transformation was done first. The error scores of the tasks with simulated devices were very skewed to the right. These scores were dichotomized ("no errors" and "one or more errors") and analyzed using logistic regression. Age, level of education and gender were entered in the first step of the regression analyses. In the second step, the frequency with which participants perform the particular TTT task in daily life was entered as a measure of experience with the device in the analysis. As regards the general scores of the TTT, the averaged use of the four devices was entered in this step. In the third step, the factors 'interest in computers and the Internet' and 'participation in intervention' were entered (both dichotomous variables). Next, visual acuity was included together with basic motor speed. In the final step, all cognitive ability measures were entered to detect an association with performance in the technological tasks.

Results

Reliability analyses

Cronbach's alpha calculated for the technological tasks at baseline was 0.55. Cronbach's alpha was 0.63 at the 12-month follow-up test. For none of the technological tasks, deletion caused an increase in Cronbach's alpha, indicating that internal consistency was not disrupted by any of the tasks. The zero-order correlations among the four technological tasks of each test administration are summarized in Table 2. The tasks were moderately, but significantly, interrelated with zero-order correlations ranging from 0.24 to 0.41.

Table 2 *Zero-order correlations between the TTT-tasks at baseline and at follow-up*

Baseline				
	CD-player	Telephone	ATM	Train ticket
CD-player	1.00	--	--	--
Telephone	0.26	1.00	--	--
ATM	0.30	0.24	1.00	--
Train ticket	0.32	0.30	0.36	1.00
12-month follow-up				
	Alarm clock	Microwave	Smartcard	Voice menu
Alarm clock	1.00	--	--	--
Microwave	0.33	1.00	--	--
Smartcard	0.40	0.41	1.00	--
Voice menu	0.23	0.30	0.29	1.00

Factor analysis showed that a single-factor solution reproduced the correlation matrix adequately. No residual correlation deviated more than 0.05 from zero in either test. The factor extracted for the baseline tasks explains 30% of the variance, whereas for the 12-month follow-up tasks this percentage is 33%. Factor loadings of each task for the factors ranged from 0.45 to 0.64 at baseline and from 0.44 to 0.68 at the 12- month follow-up, indicating that the factors explain reasonably high proportions of variance.

Regression analysis

Table 3 shows the proportions of explained variance (R^2) and the changes in the proportion of explained variance (ΔR^2) in performance times for each of the four steps in the regression model. The unstandardized regression coefficients for each of the predictors of performance time in the final steps are listed in Table 4.

Table 3 *Proportion of explained variance (R^2) of performance time for each TTT task and R^2 change (ΔR^2) for the separate steps of the regression model*

	Step 1 a)		Step 2		Step 3		Step 4		Step 5	
Baseline	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2
CD-player	.107	.107**	.120	.013	.126	.006	.134	.009	.201	.067*
Telephone	.169	.169**	.170	.002	.183	.012	.190	.008	.280	.090**
ATM	.108	.108**	.113	.005	.125	.012	.178	.052**	.234	.057*
Train ticket	.093	.093**	.148	.055**	.155	.007	.171	.016	.225	.054*
General	.201	.201**	.217	.017*	.229	.011	.259	.030*	.381	.122**
12-month Follow-up										
Alarm clock	.064	.064**	.103	.039**	.152	.049**	.158	.006	.210	.052
Microwave	.026	.026	.060	.034*	.085	.025	.099	.015	.152	.053
Smartcard	.112	.112**	.116	.003	.132	.016	.151	.020	.249	.097**
Voice menu	.195	.195**	.228	.033**	.296	.067**	.300	.004	.345	.045
General	.128	.128**	.183	.055**	.233	.050**	.241	.008	.323	.082**

Note. * $p \leq 0.05$; ** $p \leq 0.01$ *of R^2 change after each step.*

a) Step 1: age, level of education, sex; step 2: experience with the particular task; step 3: Interest in IT and participation in the intervention; step 4: vision and basic motor speed; step 5: cognitive measures

The first step, with age, level of education and sex, explained significant proportions of variance in all performance time measures, except for the microwave task. The explained proportions of variance ranged from 6.4% for the performance time for the alarm clock task to 20.1% for the general baseline score. The second step, with the frequency of use of the separate TTT devices, explained significant additional proportions of variance of the performance times of the train ticket task, the alarm clock task, the microwave task, and the voice menu task, of making errors during the train ticket task and of both general scores (the additional proportions of explained variance ranged from 1.7% to 5.5%). Step three, containing interest in computers and the Internet and participation in the intervention only explained TTT measures of the twelve-month follow up: performance times of the alarm clock task and the voice menu task, making errors during the voice menu task and the general score (additional proportion of explained variance ranging from 3.7% to 6.7%). The fourth step, containing visual acuity and basic motor spee , explained a significant proportion (additional 3.0% to 5.2%) of the performance time for the ATM task, of making errors during the train ticket vending machine task, and of the general score at baseline. The cognitive measures in the final step of the regression model explained significant proportions of variance in all baseline performance time measures, the smartcard task and both general scores. Proportions of additionally explained variance ranged from 5.4% to 12.2%. None of the error measures was sensitive to cognitive variables.

Table 4 *Unstandardized regression coefficients (B) and standard errors (SE) in the final model for all TTT tasks and both total scores*

Baseline	CD-player		Telephone		ATM		Train ticket		General	
	B	SE	B	SE	B	SE	B	SE	B	SE
Age	7.52 **	2.51	2.88	2.18	3.18	1.83	0.02	0.01	0.18 **	0.06
Education	-0.18	4.44	-17.71 **	3.83	-10.97 **	3.21	-0.01	0.01	-0.32 **	0.10
Sex	41.59 **	15.02	9.71	13.19	-4.83	10.80	0.16 *	0.06	0.66	0.34
Frequency of use	-10.06 *	4.71	4.35	5.04	-6.47	4.40	-0.09 **	0.03	-0.58 **	0.20
IT interest	18.46	18.00	12.29	15.57	24.99	12.97	-0.04	0.08	0.63	0.40
Intervention	1.10	16.01	-15.71	13.93	-0.10	11.36	-0.08	0.07	-0.09	0.36
Vision	-19.43	20.35	-9.73	17.86	-43.10	14.58	0.00	0.09	-1.03 *	0.45
Tapping	0.25	0.41	-0.14	0.36	0.03	0.29	-0.01	0.00	0.00	0.01
LDST	-1.58	0.93	-3.02 **	0.80	-0.61	0.66	-0.01	0.00	-0.07 **	0.02
VVLT 1	-5.83	4.00	-6.25	3.46	-5.34	2.85	-0.03	0.02	-0.30 **	0.09
VVLT delayed recall	0.88	2.84	4.64	2.45	4.65 *	2.02	0.01	0.02	0.15 *	0.06
CST flexibility	1.68 *	0.69	0.21	0.59	1.09 *	0.49	0.00	0.00	0.04 **	0.02
MRCT selection	-0.06	0.19	-0.06	0.17	0.20	0.14	0.00	0.00	0.00	0.00
MRCT inhibition	0.09	0.15	0.21	0.13	0.10	0.11	0.00	0.00	0.00	0.00
12-month Follow-up	Alarm clock		Microwave		Smartcard		Voice menu		General	
	B	SE	B	SE	B	SE	B	SE	B	SE
Age	1.78	1.47	-0.12	0.76	2.45	1.24	0.47	1.00	0.09	0.07
Education	-0.56	2.68	-2.56	1.36	-3.89	2.29	-8.42 **	1.82	-0.38 **	0.12
Sex	22.30 *	9.55	-2.84	4.80	14.40	8.11	-19.54 **	6.36	0.07	0.44
Frequency of use	-5.19 *	2.57	-3.60 **	1.23	-1.95	3.33	-4.52 *	2.01	-0.73 **	0.21
IT interest	12.94	10.58	1.75	5.39	-10.32	9.09	23.11 **	7.19	0.76	0.49
Intervention	-23.84 *	9.45	-8.64	4.77	-3.82	7.99	-14.36 *	6.34	-1.03 *	0.43
Vision	-6.47	11.91	-8.49	6.05	-10.57	10.14	4.19	8.06	-0.48	0.55
Tapping	-0.08	0.19	-0.08	0.10	-0.14	0.16	0.08	0.13	0.00	0.01
LDST	-0.91	0.55	-0.46	0.28	-0.98 *	0.48	-0.65	0.38	-0.07 **	0.03
VVLT 1	-3.27	2.40	0.09	1.21	-1.66	2.03	0.71	1.60	-0.10	0.11
VVLT delayed recall	-0.31	2.04	1.57	1.03	-3.00	1.74	1.05	1.37	0.03	0.09
CST flexibility	0.83	0.52	0.14	0.26	0.13	0.43	0.73 *	0.34	0.03	0.02
MRCT selection	-0.03	0.11	0.00	0.06	0.00	0.09	-0.05	0.07	0.00	0.01
MRCT inhibition	-0.04	0.09	0.08	0.05	0.17 *	0.08	0.03	0.06	0.01	0.00

Note. * $p \leq 0.05$; ** $p \leq 0.01$

Significant cognitive predictors of the separate TTT tasks and the general scores differed for each of these measures (see Table 4 for the unstandardized regression coefficients in the final model of the regression analyses). At baseline, the time needed to complete the CD player task was significantly predicted by cognitive flexibility. Participants who needed more time to switch between the two CST concepts also needed more time to complete the task. Performance in the telephone task was predicted by general cognitive speed; a larger number of boxes filled in on the LDST was associated with a shorter performance time for the task. Long-term memory and cognitive flexibility were significant predictors of the ATM task. Participants who needed less time to switch between the two CST concepts needed less time and made fewer errors. Surprisingly, participants who were able to recall more words in the delayed recall task of the VVLT needed more time to complete the ATM task. The time needed to buy a train ticket was not significantly predicted by any of the separate cognitive measures.

Finally, the general score for the four baseline TTT tasks was significantly predicted by general cognitive speed, working memory, long-term memory, and cognitive flexibility.

Participants with better scores on the LDST, the first trial of the VVLT and the CST flexibility measure had better general TTT scores. Again, surprisingly, participants who recalled more words on the delayed recall task of the VVLT had worse scores.

At the 12-month follow-up, as was the case for the baseline tasks, significant cognitive predictors of the separate TTT tasks and the general score also differed for each of the scores. Performance in the alarm clock task was not significantly predicted by any of the cognitive measures, and neither was performance in the microwave task. Significant predictors of the time needed to charge a smartcard were general cognitive speed and inhibition of a prepotent response. Participants with faster performance in regard to the cognitive measures needed less time to charge the smartcard. The number of errors was not significantly predicted by any of the cognitive measures. The fourth task, arranging travel insurance using a voice menu system, was significantly predicted by cognitive flexibility. Participants who needed less time to switch between the two concepts of the CST performed better in the voice menu task. Again, not one of cognitive measures significantly predicted the number of errors during this task. Finally, the general score of the four 12-month follow-up TTT tasks was significantly predicted by general cognitive speed. In other words, participants who performed better in the LDST were more likely to have a better general score.

Discussion

The aim of this study was to determine the role of cognitive abilities in the efficiency with which older individuals use everyday technological devices. Before answering the main question of this paper, we studied some methodological aspects of the TTT as a measure of general technological ability. Factor analyses indicated that there is one factor underlying the four tasks in each test, which in this case could be called 'general technological ability'. Because the reliability of the TTT tasks does not increase after deletion of one of the technological tasks, both at baseline and at follow-up, all tasks are considered to measure the same construct. The zero-order correlations between the separate TTT tasks in both tests showed moderate, but statistically significant, interrelations suggesting a shared underlying common factor on the one hand, and unique characteristics of each task on the other.

With respect to the role of cognitive functions, the final step of the regression model, including the cognitive variables, explained significant additional proportions of variance of most of the performance time outcome measures. This indicates that cognitive functions do play a role in the time needed to perform many everyday technological tasks.

In spite of the reasonably high proportions of explained variance of the final step in the analyses of the performance time measures, the predictive values of the separate cognitive variables did not show a consistent pattern. Overall, cognitive flexibility and general cognitive speed predicted most of the outcome measures in our analyses, followed by long-term verbal memory and short-term verbal memory. Psychomotor abilities were less strongly related to technological tasks.

The fact that cognitive flexibility was an important predictor for many of the technological tasks that were administrated here underscores the intuitive notion that this function is indeed involved in a wide variety of technological tasks. For instance, in the voice menu task participants had to switch between choosing travel insurance for countries all over the world or for countries within Europe, and pushing the appropriate buttons. In other words, first they had to do a decision task, followed by a motor task while remembering the decision that they had just made.

The second cognitive ability that predicted technological performance was general cognitive speed, or speed of information processing. A mechanism that has been described as central to the processing speed theory of differences in cognition in adults (Salthouse, 1996) and that can be applied to this context is the simultaneity mechanism. This mechanism is based on the idea that products of earlier information processing steps may be lost by the time later information processing steps are completed. For example, in the telephone-task, the procedure for programming a telephone number is quite complicated and the user has to push several buttons in exactly the right order. Because the telephone does not provide very clear feedback about the actions already taken, it is possible that older adults forget which button they pushed last when trying to decide on the next action.

The long-term memory measure was unexpectedly positively related to technological performance. Participants with better long-term verbal memory need more time to perform technological tasks. At this point we can only speculate about this finding. Perhaps these participants not only put more effort into remembering words from the VVLT, but also tried harder to remember aspects of the assignment (after the task was started) or the device and thus needed more time.

The two psychomotor measures that were also included in the analyses did not play an important role in the performance of technological tasks. This was contrary to our expectation, as both response selection and inhibition of prepotent responses (MRKT) appear to be relevant abilities in regard to technological performance. One explanation for the fact that we did not find a significant predictive effect of the ability to inhibit prepotent responses on all technological measures, except performance time for the smartcard task, may be that older adults have less experience with modern technological devices. Therefore, they may have less strongly ingrained stimulus-response combinations, and under these circumstances inhibition of prepotent responses may be a less important issue.

The cognitive predictors of technological abilities only predicted performance time measures. Whether participants made errors or not does not seem to be related to cognitive abilities (with the exception of cognitive flexibility as a predictor of the number of errors during the ATM task). However, the lack of a relationship between cognitive measures and making errors may have methodological causes as well. For instance, error scores are extremely difficult to reproduce (i.e. reliability is low) and distributions tend to be extremely skewed.

The fact that cognitive measures seem to be important in everyday technological problem solving may have important consequences for the independent functioning of older adults. Because many cognitive abilities decline as a result of normal aging processes, older adults are more likely to experience problems in the use of technological devices that are essential to daily tasks or that could enhance the autonomy of older adults. Therefore, it is important for designers of everyday technological devices to be aware of the changing cognitive capacities of older adults when developing new products (Holt & Morrell, 2002; Rogers & Fisk, 2000). For instance, based on the results of this study, these products should not place heavy burdens on the user's ability to process information by providing only relevant information at the moment this information is required. Also, the need to switch between several cognitive domains needs to be limited, for instance by providing a logical sequence of a comprehensive series of necessary actions to complete a goal. In developing a new product, designers should ideally identify the exact cognitive processes that are involved in using this product. By doing this, they will become more easily aware of design flaws and be able to adjust the design of the product to minimize the load on the essential cognitive abilities of the user.

The other steps included in the regression models showed a general significant explained proportion of variance of the demographic variables. This is consistent with the literature on cognitive aging research, in which effects of age, level of education and sex on cognitive performance are well documented (Elias, Elias, D'Agostino, Silbershatz, & Wolf, 1997; Gallacher et al., 1999). In the present study, the predictive value of age was not high, due to the limited age range of our participants (64-75 years). Level of education and sex predicted performance as was expected. Participants with higher levels of education and males were generally faster and made fewer errors.

The step including interest in computers and the Internet and participation in an Internet-related intervention only explained significant proportions of variance in TTT tasks that were administered at the 12-month follow-up measurement. It is remarkable in this respect that participants with interest needed more time overall and made more errors. As this finding is difficult to explain and this measure did not significantly predict any of the other measures, we suppose that this is a chance finding. At the twelve-month follow-up, individuals who had participated in the intervention performed both the alarm clock task and the voice menu task faster and had better general scores. This may be indicative of generalization of computer and Internet skills obtained during the intervention period in regard to the efficient use of technological devices in daily life. This finding will be discussed in more detail in a forthcoming paper about the intervention study.

The major appeal of the Technological Transfer Test is its ecological validity. Despite the fact that following instructions to perform an assignment is not completely identical to technological activities in daily life, we feel that this is a feasible and reliable way to quantify the efficiency of everyday technology use. It was not possible to assign the exact same test twice to the same participants because of learning effects, which were expected to be quite large. We tried to circumvent this by designing eight different technological tasks that were balanced over the two measurements with respect to expected experience and difficulty with the particular devices because no validated instruments were available from earlier research. Altogether eight tasks were included, representing a broad domain of everyday technological tasks and providing parallel tests to enable repeated testing. This test is a first method for generating hands-on quantitative data about the efficiency of dealing with actual existing everyday technological devices. The large group of participants in this study and the two parallel versions of four tasks in each of these tests enabled us to thoroughly study cognitive predictors of technological efficiency that is essential to everyday functioning.

Overall, based on the present study we can confirm that cognitive abilities play a role in the execution of technological tasks that are part of daily living. Of course, cognitive effects are task dependent. In general, of all cognitive measures, cognitive flexibility and general speed of information processing were found to predict performance in the largest number of the technological tasks in this study. Since further knowledge about the role of cognitive skills when dealing with everyday technology is still very scarce, especially in older adults, future research should focus on further developing methodologies to measure technological skills. Also, for the design of technological products older adults are able to use without problems, one should focus on the exact cognitive abilities that are drawn upon when performing tasks with technological devices.

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Chapter 7

The effects of computer training and Internet usage on the use of everyday technology by older adults: A randomized controlled study

Submitted for publication

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Abstract

According to the concept of skill transfer, people may be able to use general technological skills to solve new technological problems. To test whether this transfer actually occurs or not, a new test of technological efficiency was included in a randomized controlled intervention study that aimed to examine the causal relationship between computer use and autonomy of older adults. A large group of 191 participants were randomly assigned to an Intervention Group, a Training/No intervention group or a No training/No intervention Group. A fourth group consisted of 45 participants with no interest in computer use. Exposure of older adults to a novel technological challenge was not found to affect the efficiency of and involvement in other technological activities.

Being able to use modern everyday technology has become increasingly important in regard to older adults remaining autonomous. For instance, in many places public transportation tickets can only be purchased at vending machines and money from a bank account can only be withdrawn at a cash machine. Besides this necessity to use technological applications, technological devices may also provide opportunities to increase the autonomy of older adults (McCreadie & Tinker, 2005; Zimmer & Chappell, 1999). Devices such as microwave ovens and microcomputers providing medication reminders can assist older adults in their everyday lives and allow them to live independently, even when they are in need of assistance.

Older adults often experience problems when using these modern technologies. It has been shown in several studies that, for instance, older adults need more time to learn to use a computer system, make more errors and require more help (e.g. Kelley & Charness, 1995). Another example of a technological task which has been shown to be more difficult for older persons is the use of automatic teller machines (Rogers, Gilbert, & Fraser Cabrera, 1997).

Several attempts have been made to train older adults in the use of specific technological applications, such as the Internet (Cody, Dunn, Hoppin, & Wendt, 1999), the use of a word processor (Charness, Bosman, Kelley, & Mottram, 1996) or an automatic teller machine (Rogers, Fisk, Mead, Walker, & Cabrera, 1996). In order to improve technological skills on a more general level, ideally the training of a specific technological skill should generalize to skills needed under different technological demands. This use of previous experience to devise a solution for a new problem or task has been described as 'problem-solving transfer' (Mayer & Wittrock, 1996). Several views on transfer have been described by Mayer and Wittrock (1996). According to these authors, in order to yield the transfer of general skills learned in one situation to a novel situation, the aim should either be on the specific transfer of general skills or on the metacognitive control of general and specific skills.

According to several authors (Jelsma, van Merrienboer, & Bijlstra, 1990; Sweller, 1989), the two most important cognitive processes in the successful transfer of problem-solving skills are schema acquisition and rule automation. A schema is a mental framework in which related concepts are organized in a meaningful way, based on previous experience (Sternberg, 1996). Each time a problem within the domain of this schema is solved, the schema is expanded with newly acquired skills and rules. When faced with a novel problem, individuals can use existing schemata that provide analogies based on previous experience with similar problems by mapping processes to solve unfamiliar parts of the new task (Paas & van Merrienboer, 1994). In the context of older adults learning to use a new technology, this might imply that individuals acquire and expand some kind of "technology" schema, which enables them to recognize analogies between familiar and unfamiliar technological applications. As a result of this, solving a new technological problem may be facilitated. In this respect, individuals with computer experience will acquire a "computer schema" with knowledge about several concepts that are central to the functionality of a computer system. They know, for example, that not all of the necessary options are available at once, but that specific options become available at specific levels of the menu structure. This concept is also embedded in a computer-based device such as an ATM, in which a button can be used at one level to choose the appropriate amount of money, while at the next level the same button is used to confirm the option.

The second cognitive process essential to transfer of problem-solving skills, the automation of rules, is in fact a task specific procedure. This process can provide identical elements that are helpful in new tasks (Paas & van Merrienboer, 1994). Thus, when a novel technological task consists of elements that were processed by automated rules in earlier tasks, these automated rules also facilitate solving a new technological problem. For instance, applications that are operated by using a touch screen usually have in common that the touch screen has to be touched before the main menu options become visible. Therefore, the rule "touch the touch screen to activate it" can be applied to many different applications.

Not only may newly acquired technological skills be transferred to the use of other technological devices, individuals who master some technological skills may also feel more confident in using technology in general. As a result, they start using other technological applications as well and might experience fewer problems. In research into computer anxiety for instance, where it has been suggested that computer anxiety prevents individuals from using computers (Harrington, McElroy, & Morrow, 1990; Rosen & Weil, 1995), it has been shown that positive experiences with computers may lead to decreases in anxiety (Chu & Spires, 1991). Thus, acquiring general technological skills should result in lower levels of perceived difficulties with and in a higher frequency of the use of everyday technological devices. Therefore, teaching older adults general technological skills may be an effective strategy in improving their autonomy.

Problem-solving transfer is a very promising concept in the present context of teaching older adults technological skills they could use to solve unfamiliar technological problems they encounter in everyday tasks. However, transfer seems to be a rare phenomenon in laboratory studies (Mayer & Wittrock, 1996), which is often considered one of the main problems in instructional methods (van Gog, Paas, & van Merrienboer, 2004). Also, research focusing on skill transfer in older adults is particularly scarce and most often aims at the transfer of very specific cognitive abilities or at the transfer of cognitive training to everyday problem solving. For instance, Fernandez-Ballesteros and Calero (1995) showed that training in inductive reasoning skills and spatial orientation skills resulted in improvements in both the domain and a transfer test. Transfer of similar specific cognitive skills to measures of everyday functioning, such as everyday problem solving, were not found in an intervention study by Ball et al. (2002). Because technological performance has become an increasingly large part of everyday functioning, intervention programs aimed at increasing the autonomy of older adults should include a measure of the degree of technological performance in order to measure the impact of the intervention.

Before developing specific strategies that focus on the transfer of technological skills to novel technological problems that older adults are faced with in everyday activities, it is important to study whether this transfer can actually be achieved. Otherwise, research should focus on different approaches of reducing older adults' problems with technology, such as perhaps more specific training methods or design solutions. The aim of the current research therefore was to study whether or not newly acquired general technological skills help older users to perform technological tasks in other areas of daily life. That is, are older adults able to apply newly acquired technological skills to new situations in which they are confronted with other technological task demands? And, do older adults report higher frequencies of using everyday technologies and fewer difficulties with this use as a result of newly acquired technological skills?

We addressed these questions in an intervention study into the impact of computer training and Internet use on the functional status of older adults. Due to the randomized design of this intervention study, we were able to study these hypotheses using a strictly controlled approach. To our knowledge, this has not been done before, as previous research on the transfer of problem-solving and other cognitive skills has mainly focused on the specificity of transfer and on educational strategies to increase the level of transfer in younger adults (Paas & van Merrienboer, 1994; Phye, 2001; Spaulding & Phipps, 1997; Speelman & Krisner, 1997; van Merrienboer, de Croock, & Jelsma, 1997).

The present intervention program provides a first opportunity to experimentally study whether older adults are able to transfer newly acquired computer skills to the execution of everyday technological tasks in a large group of participants. As this study consists of three control groups in addition to the intervention group, the effects of using a computer and the Internet for twelve months, of computer training and of a participant's interest in learning to use computers could be separately investigated. The distinction between the twelve-month computer use and the training is important because when skill transfer occurs, this provides information about the amount of computer experience that is required for transfer to occur. Whether participants are interested in computers and the Internet or not may also be connected to technological skills. Perhaps individuals who are enthusiastic about learning to use computers are less reluctant about everyday technology before they have actually used computers in the first place.

In accordance with the theory of problem-solving transfer, it was hypothesized that technological skill transfer would occur, and that older adults who acquire computer skills in a one-year period would show higher efficiency in several everyday technological tasks (that is, they would act faster and make fewer mistakes). With respect to the frequency of and difficulty with performing everyday technological tasks, it was hypothesized that mastering computer skills in older adults would result in an increase in the frequency of using everyday technological devices and a decrease in the difficulty older adults experience in using these devices. The frequency and perceived difficulty with these everyday technological tasks were measured by means of a structured questionnaire.

The technological tasks included in the present study were tasks that older adults are likely to be required to perform in daily life. For instance, in many Western European countries, paying for a parking ticket is in many places only possibly by using a smartcard, and many companies can only be reached by telephone by means of a computerized voice menu system. To study whether technological computer skills are only transferred to computer-based tasks or also to other types of technological tasks, which would mean a more general transfer, both computer-based tasks and tasks with devices that are not strictly computer-based were included (see Table 1 for an overview of the used devices and tasks).

Many computer-related skills may be required for performance of both computer-based and other types of technological tasks. For instance, when charging a smartcard, one of the tasks that were used in the present study, the user receives feedback on every action and has to make an appropriate response based on this feedback (e.g. when the feedback on the display tells the user to input the amount to charge, it is of no use to input the PIN code or to press the "OK" button). The same applies to devices that are not computer-based. For example, to set the correct time on an alarm clock, the user has to keep track of information on the display to make sure of which button to press and how many times to press this button. Therefore, it was expected that teaching older adults general computer skills will affect both computer-based devices and devices that are not directly computer-based.

The research topics that are central to this paper are relevant to the question of whether transfer of technological skills in older adults is likely to occur. If this is the case, training in technological skills may provide a solution to the problems older adults experience with technological applications. This would result in older adults experiencing fewer problems in using technology and being able and willing to use new assistive products, and therefore contributing to maintaining an independent lifestyle in later life. If transfer is not observed, other solutions will have to be found.

Methods

For information about the participants and the procedure of the intervention study, see Chapter 3. For the purpose of this paper, baseline and twelve-month follow-up data were used.

Measures

Technological efficiency. To measure the efficiency of using everyday technology, the Technological Transfer Test (Slegers, van Boxtel, & Jolles, 2005) was administered twice during the intervention study, once at baseline and once after twelve months. On both occasions, participants were instructed to successfully operate four technological devices that are commonly used in daily life (see Table 1).

On each test occasion, two of the devices that were used for testing were real life consumer devices. The other two were common, public technological devices, simulated on a computer that could be operated with a touch screen interface. The simulated devices were developed so that the procedures and interfaces exactly matched the original interface.

Table 1 *Overview of the technological transfer test devices and assignments*

Device	Type	Assignment
Baseline		
CD player	real	"Play song number four from this CD."
Telephone	real	"Program this phone number in the memory of this phone."
Automatic teller machine	simulated	"Withdraw the maximum amount of money from this bank account."
Train ticket vending machine	simulated	"Buy a return ticket to the city of Eindhoven."
12-month follow-up		
Microwave oven	real	"Heat up this glass of water for 60 seconds."
Alarm clock	real	"Set the alarm clock for 7:15 am. tomorrow."
Smartcard charger	simulated	"Charge this smartcard with 150 Euros."
Telephone voice menu	simulated	"Arrange travel insurance for a holiday in Spain."

Participants received written instructions for each device. For the real life devices, the instruction sheet also contained brief directions for use (derived from the original instructions supplied with the devices). Participants were instructed that they could refer to these instructions, if needed. Participants were asked to complete the assignments as fast and as accurately as possible. The experimenter was not allowed to intervene during the task or assist the participants in any way.

The performance time (for all types of devices) of each task and the number of errors participants made before completing the task (for the simulated devices only, because a log file of the participant's actions was available for these devices) were used to measure the efficiency of completing the aforementioned assignments. Finally, for both administrations, an overall performance time score of the four tasks was computed on each test occasion. As the tasks were quite different with respect to the time it took to perform the assignments, z-scores were used for individual scores, which were added up to the overall scores.

Use of everyday technology. To measure the use of everyday technology, participants were asked to indicate the frequency with which they performed 17 specific technological tasks (e.g. sending a fax, programming a video recorder or buying a parking ticket) and the difficulty they experienced when performing these tasks. Frequency was measured using a five-point scale ranging from "never" to "at least once a week". Difficulty was also rated on a five-point scale, ranging from "very easy" to "very difficult". Data collected at the baseline and twelve-month follow-up questionnaires were used.

Two general measures of technology use were calculated. First, as a general measure of the frequency of using everyday technology, the mean frequency of performing the tasks participants stated they perform regularly was used. Second, the mean difficulty participants experience with performing these tasks was calculated. In the analyses, these measures were corrected for the number of tasks participants stated they perform.

Statistical analyses

Statistical analyses were performed with the SPSS v11.0 program series for Apple Macintosh. The alpha level was set at .05. To study demographical differences between the four groups at baseline, ANOVAs were conducted on the dependent variables age and level of education. Differences with respect to sex were analyzed using a Chi-square test.

Effects of intervention. Group differences in performance time for each of the TTT tasks were studied using univariate ANOVAs with age, level of education, sex and the frequency of performing the particular tasks in everyday life as covariates. As the outcome of the train ticket vending machine task was not normally distributed, a log-transformation was done first. The number of errors made on each of the simulated tasks was analyzed with the Kruskal-Wallis test, as these variables were skewed to the right.

To measure the effect of the intervention on the overall scores and both use of technology scores (frequency and difficulty), a General Linear Model (GLM) with repeated measures analysis of variance was used. Analyses were conducted with group as between-subject variable (four levels) and time as within-subject variable (two levels). Contrasts were defined to compare changes in performance over time (between baseline and follow-up) of the four groups. Age, level of education and sex were used as covariates, and in the analyses of the frequency and difficulty scores the number of technological tasks participants stated they perform regularly was added to the set of covariates. We specifically tested the interactions of time and group, as these interactions show whether the groups differed from one another with respect to changes over time in the dependent variables.

All analyses were repeated with only the individuals in the Intervention Group to account for the extent of computer use. In these analyses the between-subject variable 'extent of computer use' had two levels: light and heavy. This variable was calculated by using a median split method on the number of hours per week participants said they used their computers at the twelve-month follow-up moment. In this case the median was 7.5 hours, so participants who reported using their computers 7 hours per week or less were labelled 'light users' and participants who reported using their computers 8 hours per week or more were designated 'heavy users'.

Results

At baseline the four groups did not differ with respect to age, sex and level of education. Baseline comparisons of participants who dropped out of the study at some point (n=36) with participants who completed all test administrations (n=198) showed differences in level of education ($F(1, 229)=4.13$, $p=.04$), in the mean difficulty of performing technological tasks ($F(1. 221)=8.99$, $p<.01$) and in the number of technological tasks participants stated they perform regularly ($F(1, 229)=23.20$, $p<.01$). Participants who dropped out had lower educational levels, a lower mean difficulty with performing technological tasks and performed fewer technological tasks. As regards the measures of the use of everyday technology, one group difference was found at baseline ($F(3,226) = 5.167$, $p < .01$): participants in the Intervention Group showed higher scores on the general frequency score, corrected for the number of tasks regularly performed, than participants in the Control Group ($p < .01$).

Technological efficiency

The mean performance times and number of errors of the four groups for all the technological tasks are listed in Table 2. At baseline, no differences between the groups were found with respect to performance time and the number of errors participants made on the TTT tasks. Also, no group differences with respect to the overall score were found. At the twelve-month follow-up, group differences were present in regard to the performance time on the alarm clock task ($F(3,182) = 3.608$, $p =.01$), the voice menu task ($F(3,178) = 6.145$, $p < .01$) and the number of errors participants made on the voice menu task ($\chi^2(3, N = 200) = 9.435$, $p = .02$). Post hoc pair wise comparisons (adjusted for multiple comparisons using Bonferroni correction) showed that participants in the Intervention Group needed less time than participants in the Training/No intervention Group to complete the alarm clock task ($p = .02$) and the voice menu task ($p =.02$). On the latter task, it was also found that participants in the Control Group were faster than participants in the Training/No intervention Group ($p <.01$) and participants in the No training/No intervention Group ($p = .04$). Finally, pair wise comparisons of the mean number of errors participants made on the voice menu task showed that participants in the Control Group made fewer errors than participants in the Training/No intervention Group ($p < .01$).

Table 2 *Mean (SD) performance time (seconds) and mean (SD) number of errors for the TTT tasks and mean overall performance time scores on baseline and twelve-month follow-up for the four groups*

	Intervention			Training/ No intervention			No training/ No intervention			Control Group		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Baseline												
time telephone	62	136.66	82.36	60	164.85	110.25	68	150.56	96.95	45	137.15	93.13
time CD player	62	202.70	93.50	60	239.05	109.43	68	202.01	106.39	45	203.32	113.83
time ATM	62	123.92	79.93	60	135.42	92.42	67	123.06	75.08	44	104.77	54.72
errors ATM	62	4.69	4.38	60	4.58	5.66	67	5.03	4.75	44	3.73	3.11
time train ticket	62	58.77	35.95	59	68.22	39.86	67	65.24	34.95	44	68.93	36.51
errors train ticket	62	0.35	0.85	59	0.64	1.21	67	0.63	1.17	44	0.91	1.83
overall score	62	-0.37	2.85	59	0.67	2.96	67	-0.07	2.57	44	-0.33	2.42
12-month follow-up												
time microwave	58	39.34	18.21	49	49.86	36.07	55	48.16	27.91	40	47.94	23.49
time alarm clock	58	90.42	45.91	49	121.50	55.67	55	111.20	62.23	40	102.54	62.55
time smartcard	58	87.72	40.85	49	105.37	61.39	55	88.58	39.55	40	107.90	55.30
errors smartcard	58	1.76	1.86	49	1.98	2.46	55	1.47	1.65	40	2.15	1.85
time voice menu	58	181.41	35.22	48	202.65	48.06	55	192.15	37.90	39	170.41	38.72
errors voice menu	58	0.90	1.37	48	1.13	1.45	55	0.91	1.18	39	0.38	0.71
overall score	58	-0.83	2.27	48	0.96	3.46	55	0.13	2.38	39	-0.15	2.91

All analyses were repeated with extent of computer use as the between-subjects factor to study whether there were any differences between participants in the Intervention group who used their computers more often and participants who used their computers less often. No differences were found with respect to the separate TTT tasks between light and heavy computer users.

GLM repeated measures ANOVA was done to study whether the intervention caused changes in a general measure of technological efficiency. For this purpose, the overall measure of the four TTT tasks at both test administrations were used as the dependent variable. No differences were found between the groups in changes on this general technological efficiency score over time.

This repeated measures analysis was also done on the extent of computer use in the Intervention Group as between-subjects factor. In the light use group, participants used their computer with an average of 3.73 hours per week (*SD*=1.97). Average use in the heavy computer group was 12.93 hours per week (*SD*=5.46). It was found that heavy computer users did not show different patterns of change with respect to general technological efficiency compared with light computer users.

Use of everyday technology

The mean frequency and the mean difficulty of the use of 17 everyday technological devices as well as the mean number of devices used are listed for each group at baseline and at 12-month follow-up in Table 3. GLM repeated measures ANOVA was done for the general frequency of everyday technological tasks and the general difficulty with everyday technological tasks. It was found that there were no differences between the four groups with respect to changes over time in respect of both measures.

The same analyses were done with extent of computer use in the Intervention Group as the between-subjects factors. Again, the results showed no significant differences in changes over time with respect to frequency of and difficulty with everyday technological tasks between heavy and light computer users.

Table 3. *Mean (SD) frequency and difficulty of the use of everyday technological devices and the mean (SD) number of devices used by the four groups at baseline and the twelve-month follow-up*

	Intervention			Training/ No intervention			No training/ No intervention			Control Group		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Baseline												
mean frequency	61	2.93	0.69	60	2.67	0.56	66	2.69	0.53	43	2.52	0.60
mean difficulty	59	1.89	0.55	60	1.88	0.66	65	1.96	0.58	43	2.19	0.83
number of devices	62	16.47	2.37	60	16.92	0.42	68	16.28	3.05	45	15.98	3.74
12-months follow-up												
mean frequency	57	3.03	0.77	47	2.65	0.57	53	2.71	0.58	39	2.53	0.58
mean difficulty	55	1.84	0.55	46	2.00	0.66	52	2.05	0.62	37	2.11	0.76
number of devices	60	15.44	4.70	49	13.12	6.98	55	13.03	7.05	40	14.53	5.86

Discussion

The first aim of the present study was to determine whether older adults who mastered personal computer skills showed evidence of skill transfer to other everyday technological tasks. The results did not support this hypothesis: no effect of the intervention was found in the efficiency of using everyday technological devices, both computer-based and other types of devices. Hence, transfer of newly acquired computer skills did not occur.

Some group differences were found with respect to performance of the TTT tasks that were administered after the intervention, while at baseline no differences were found. Actually, at baseline, the Intervention Group showed the fastest mean performance time on two out of four tasks (though not statistically significant), and at follow-up, this group showed the fastest performance time on three out of four tasks (statistically significant in two of the tasks: the alarm clock and the voice menu task). This might reflect a trend towards an effect of the intervention. However, for both the alarm clock task and the voice menu task it was found that the Intervention group outperformed the Training/No intervention group, but not the other two groups. This difference can therefore not be considered a direct effect of computer use. In case of a robust effect of intervention, group differences between the Intervention Group and the No training/No Intervention Group and the Control group should also have been present. Visual inspection of the data showed that participants in the Training/No intervention group almost consistently needed more time for all of the technological tasks compared with the other groups. Therefore, the group differences in performance time after the intervention are most likely considered to be chance findings.

One group difference was found with respect to the number of errors that was made on the separate TTT tasks. Participants in the Control Group needed the fewest steps to complete the voice menu task. Again, in case of a transfer of newly learned computer skills, it was not expected that participants in the Control Group outperformed participants in the Intervention Group or the Training/No intervention Group.

In line with the aforementioned results, with respect to the second aim of this study, no effect of intervention was found on either the frequency of or the difficulty with performing everyday technological tasks. In other words, older adults who have mastered personal computer skills and gained computer experience for twelve months do not show higher frequencies or fewer difficulties in the use of everyday technological devices.

Summarizing, no evidence was found that transfer of technological skills to the efficiency in performing everyday technological tasks occurred as a result of the intervention. In terms of problem solving transfer, we have found that although older adults in this study most probably acquired and expanded a schema with respect to using a computer, they were not able to use this schema when confronted with other, and in many respects quite similar technologies. The same applies to the process of rule automation. After using a computer and the Internet for twelve months, which we were able to monitor by means of the response to our regular e-mail assignments sent out to the participants in the Intervention Group, it is highly likely that the participants automated at least some common computer-related rules. Apparently, the participants were not able to apply these rules to the use of everyday technologies. Finally, gaining general computer skills has also not encouraged our participants to use everyday technological devices more often and they still experience equal amounts of difficulty with these devices.

Because the present study did not show any transfer of computer skills to the execution of everyday technological tasks, teaching basic technological skills is not an effective strategy for increasing the efficiency, frequency and ease of use of everyday technological applications for older adults. Therefore, future research should aim at identifying and developing other types of strategies to improve older adults' execution of everyday technological tasks. Such strategies may be a more specific training method instead of teaching general technological skills, design solutions that take older adults' capacities into account, or an approach with a focus on technology generations (Docampo Rama, 2001), as individuals in older generations gained most of their technological experience at a time that technology was much more electro-mechanical whereas nowadays it is more display-based and menu-structured. Finally, there may be a role for psycho education. For instance, it has been suggested that general anxiety and the way people relate the requirements of technology to their own capacities (or perceived behavioural control) prevent individuals from using computers (Hone, Graham, Maguire, Baber, & Johnson, 1998; Morris & Venkatesh, 2000). Therefore, education that aims at reducing these psychological obstacles older adults face when adopting new technologies may prove to be of value.

The major strength of the present study is the ecological validity of the Technological Transfer Test. As real life tasks and technological devices were used, we were able to study participants' performance of tasks they are likely to encounter in their daily life in a large group of older adults. It was not possible to administer the exact same test twice to the same participants because of learning effects, which were expected to be quite large. We have tried to solve this by designing eight different technological tasks that were balanced over the two measurements with respect to expected experience and difficulty with the particular devices, as no validated instruments were available from earlier research. In total, eight tasks were included, to represent a broad domain of everyday technological tasks and to provide parallel test administrations to enable us to administer pre and post tests to assess the effect of both twelve-month computer use and computer training in a large group of older adults.

The fact that we have not found any transfer of newly acquired computer skills to performance of everyday technological tasks may imply, as was explained above, that the theory of skill transfer does not work with respect to technological skills. On the other hand, there may also be other reasons for the lack of transfer in the present study. A first explanation is that the basic computer skills that were acquired by participants in the present study are not sufficiently similar to the skills required by the technological tasks. However, this is not very likely because mastering computer skills would probably cause an expansion of the "technology schema" of the participants and thereby result in more available skills and rules to solve other problems. In addition, most of the technological applications today require actions that are almost identical to those required when using a personal computer (such as pushing a button on screen). A possibility in this context is that people did not recognize the analogies between using a computer or the Internet and other applications, a problem that is mainly observed in situations of transfer between different domains and superficially different analogies (Catrambone & Holyoak, 1989). As a result of this lack of noticing analogies, participants in this study may not have been able to use their computer schema and to apply automated rules gained when using their computers. However, it was not possible in this study to determine whether participants made any analogies between the TTT tasks and their computer-related skills. An aim for future research therefore may be to explore this question further and develop strategies to help individuals recognize similarities between elements of novel and familiar technological tasks.

Another explanation for the lack of transfer is the fact that the everyday technological tasks were identical to real life tasks and therefore not entirely new for all participants. That is, to solve the TTT tasks, participants who were already familiar with these tasks used their own existing strategies and were not inclined to transfer any new skills. On the other hand, gaining relevant technological experience, such as computer skills, should also help individuals who have some experience with the tasks at hand because these skills enable them to work more efficiently. This is supported by the fact that our analyses were controlled for the experience participants already had with the separate TTT tasks and by repeating the analyses with only those participants who had never performed the tasks, which did not change the pattern of observed effects (n = 133 for the telephone task, n = 36 for the CD player task, n = 14 for the ATM task, n = 146 for the train ticket vending machine task, n = 53 for the microwave oven task, n = 73 for the alarm clock task, n = 144 for the smartcard task and n = 127 for the voice menu task).

In conclusion, the mere acquisition of computer and Internet skills is not a successful strategy for obtaining transfer of technological skills essential to everyday independent functioning in later life. Research in this area is very scarce, and because the present study in a large group of participants did not yield any evidence to suggest that transfer of technological skills actually occurs, we feel that more research should be done to develop efficient methods to improve technological efficiency. Also, it may be worthwhile to outline possible conditions under which transfer of technological skills in older adults does occur. For instance, future research may focus on more generic technological skills that underlie many technological tasks and on the psychological barriers that might lie beneath problems with technology. Also, the question of whether older individuals recognize analogous aspects of technological problems, which is essential to the transfer of skills and rules acquired in earlier problems, should be considered more specifically in such studies.

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Chapter 8

Computer anxiety in older adults with no computer experience: Predictors and the effects of computer training and Internet usage in a randomized controlled study

Under revision

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Abstract

Computer anxiety has been found to prevent individuals from using computers. This study aimed at identifying predisposing factors (in the realm of demography, personality and perceived control) of computer anxiety. Also, the impact of computer training and Internet use for a twelve-month period on changes in computer anxiety level was investigated. A large sample of 236 healthy older individuals (64-75) with no prior computer experience was investigated as part of a randomized controlled intervention study. The results showed that older individuals without active computer experience who were interested in computers and the Internet and who were more extravert had lower levels of computer anxiety. Also, computer anxiety did not change as a result of computer use. It is concluded that prevention programs should account for age-specific predictors of computer anxiety and that exposure to computer use is not an effective strategy for reducing computer anxiety.

It is becoming increasingly difficult to function independently in modern Western society without the ability to use information technology (IT). For instance, buying a parking ticket in many places is very often only possible at a computerized ticket vending machine with the use of a smartcard. This societal development is especially relevant to older adults as they have less experience and more problems with using IT (Czaja & Sharit, 1993; Czaja & Sharit, 1997; Kelley & Charness, 1995; Mead, Spaulding, Sit, Meyer, & Walker, 1997; Mead, Jamieson, Rousseau, Sit, & Rogers, 1996; Walker, Millians, & Worden, 1996). Acceptance of and adaptation to daily life technologies that may support their autonomy at a later stage in life is particularly important to older individuals. However, it has been suggested that computer anxiety withholds individuals from using computers (Harrington, McElroy, & Morrow, 1990; Rosen & Weil, 1995) and potentially also from using other computer-based technologies.

The most important predictor of computer anxiety has often been found to be computer experience (Anthony, Clarke, & Anderson, 2000; Beckers & Schmidt, 2003; Chua, Chen, & Wong, 1999; Farina, Arce, Sobral, & Carames, 1991). Individuals with more computer experience tend to show lower levels of computer anxiety. Besides experience, several other predictors of computer anxiety have been suggested as well. Sociodemographic factors were found to correlate with computer anxiety but the findings have not been very consistent. In a meta-analysis of 36 studies published between 1990 and 1996, Chua et al. (1999) found inconsistent results for the relationship between computer anxiety and sex; in some studies it was found that women showed higher levels of computer anxiety, while other studies showed no significant relationship. Also, Chua and colleagues mention that many studies found no relationship between age and computer anxiety and that only studies that used broad age ranges tend to find positive relations between age and computer anxiety. With respect to level of education, Beckers et al. (2002), who also found significant relationships between computer anxiety and both sex and age in a sample of 495 "technology smart" participants, showed that participants with higher levels of education had lower computer anxiety scores. Other predictors of computer anxiety that were suggested include general anxiety level (Farina et al., 1991), personality traits (Anthony et al., 2000; Sigurdsson, 1991) and perceived control (Parasuraman & Igbaria, 1990).

Research focusing on computer anxiety in older populations is fairly limited and although it has been found that older adults are willing to learn to use computers and also tend to enjoy it (Czaja, 1996; Morrell, Mayhorn, & Bennett, 2000; Rogers & Fisk, 2000), they generally have little computer experience. While predictors of computer anxiety have mainly been studied in student populations including individuals with at least some experience, little is known about computer anxiety in individuals without any computer experience, which is fairly common in older populations (de Haan, 2003). The first research question in the present study therefore concerned predictors of computer anxiety in older adults without computer experience; are these similar to predictors of computer anxiety in individuals who are already used to computers? This question is important with respect to computer training programs or interventions set up specifically for older adults and for individuals with no prior computer experience. More dedicated knowledge of the causal and reinforcing factors of computer anxiety may improve the efficiency of such training programs.

The second question of this study concerned the effect of gaining computer experience on experienced computer anxiety. It has been shown, again mainly in samples of individuals who already had some computer experience, that positive experiences with computers can decrease computer anxiety (Chu & Spires, 1991). However, finding no differences in computer attitudes as a result of computer training has also been reported (Czaja, Hammond, Blascovich, & Swede, 1989). Based on these mixed findings, it was suggested that both the duration and the type of exposure to computers may affect changes in computer attitudes and anxiety (Charness, Schumann, & Boritz, 1992) and that longer exposure durations may be necessary to yield those changes (Jay & Willis, 1992). More conclusive knowledge is needed on the type and duration of intervention strategies that may reduce or prevent computer anxiety in older adults with no computer experience. Therefore, we included a measure of computer anxiety (the computer anxiety scale of Beckers and Schmidt (2001)) in a long intervention program (twelve months), while most of the prior research used training programs of only a few weeks. This program was aimed at studying the impact of computer training and Internet use on the autonomy of older adults. By including this measure, we were able to study predictors of computer anxiety in computer naïve older adults and the effect of gaining computer experience on computer anxiety.

The intervention in this study involved using personal computer and Internet services for a twelve-month period. The rationale behind this study was the notion that cognitively challenging activities may boost the cognitive abilities of older adults, expressed in both the notions of 'Use-it-or-lose-it' (Hultsch, Herzog, Small, & Dixon, 1999) and 'cognitive reserve' (Stern, 2002). The use of a computer and the Internet provides divergent cognitive challenges to older persons, and positive effects of computer and Internet use on the quality of life were found in earlier studies (e.g. Cody, Dunn, Hoppin, & Wendt, 1999; White *et al.*, 2002). Therefore, this intervention study focused on several aspects of autonomous functioning, reflected in both cognitive measures and measures of wellbeing.

Baseline data were used to study the first question concerning predictors of computer anxiety. Based on the predictors of computer anxiety that were suggested by the studies in younger populations discussed above, we included the following variables in a model of potential predictors: age, sex, level of education, general anxiety, personality (neuroticism and extraversion), and a measure of perceived level of control over life. Also, it was decided to include measures of perceived health status and of the actual use of everyday technologies. As our study population did not have any actual computer experience, the latter measure may give some indication of the proneness to use computer-related technology.

Changes in computer anxiety during the intervention period were measured in order to study the second question regarding the effect of using computers and the Internet on computer anxiety in novice older computer users. Participants in this study were randomly assigned to a Training/Intervention Group, a Training/No intervention Group and a No training/No intervention group. In addition, a group of participants who were not interested in computers and the Internet were assigned to a Control Group. By randomly assigning the participants to these four groups, it was possible to specifically distinguish the effects of interest in computers, of computer training and of the intervention (that is, using a computer and the Internet for twelve months). Our hypothesis was that older adults who gained computer experience for a one-year period show a reduction in computer anxiety, while this score remains stable in the other groups.

As several earlier studies showed a relationship between computer anxiety and the actual use of computers (Beckers & Schmidt, 2003; Bozionelos, 2004), a final research question in this paper was whether older adults in the Intervention Group with high computer anxiety scores at baseline used their computers less often and less extensively. Also, we hypothesized that participants who used their computers more often and more extensively in the period after the start of the intervention showed a decrease in their computer anxiety scores.

The strength of this study is that, because of the large sample and the strictly controlled design with three control groups, we are able to draw firm conclusions as to whether the intensive intervention that was used here is effective and whether it is worthwhile implementing such an intervention on a large scale. Also, this study provides more conclusive knowledge into computer anxiety in older adults without computer experience, which is relevant to preventing and reducing computer anxiety in this population. Finally, this study provides insight into the effect of very long durations of computer exposure on computer anxiety, which has not been done before for such a long period.

Methods

For information about the participants and the procedure of the intervention study, see Chapter 3.

Measures

Computer anxiety. The Computer Anxiety Scale of Beckers and Schmidt (Beckers & Schmidt, 2001) measures six factors of computer anxiety: computer literacy, self-efficacy, physical arousal in the presence of computers, affective feelings towards computers, positive beliefs about the benefits of computers for society, and negative beliefs about the dehumanizing impact of computers. The short version of this scale that was used in this study contains 32 items, consisting of statements on computers that were scored on a five-point Likert scale ranging from “entirely disagree” to “entirely agree”. A total score of this scale was computed, with a maximum of 24. Low scores indicate little or no computer anxiety, and high scores indicate high levels of anxiety.

Predictors of computer anxiety. To account for sociodemographic variables, age, sex and level of education were included in the analysis. Level of education was measured on an eight-point scale as used by Statistics Netherlands (De Bie, 1987). The scale ranges from primary education to higher vocational training and university degree. Also, as both individuals with and without an interest in computers and the Internet participated in the study, we included the factor "interest in computers" in the analysis.

Because the participants in this study had no computer experience and because many everyday technological appliances are computer based, we assessed the use of everyday technology to account for computer experience that was gained without actually using computers. To measure this use of everyday technology, participants were asked to indicate on a list of 17 everyday technological devices (such as a digital alarm clock or an automatic teller machine) how frequently they used such devices. For the purpose of this study, the total number of devices participants indicated using was calculated.

Other variables that were expected to predict computer anxiety were general anxiety, personality (neuroticism and extraversion), mastery and perceived health status. To measure general anxiety, the anxiety subscale of the Symptom Check List (SCL) 90 (Arrindell & Ettema, 1986) was used. Neuroticism and extraversion were measured with the Eysenck Personality Questionnaire (EPQ) (Eysenck & Eysenck, 1975) and the Mastery scale (Pearlin & Schooler, 1978) was used to ask participants about their perceived level of control over their life. Finally, participants were asked to rate their own health status (five-point scale ranging from "bad" to "excellent").

Measures of computer use in the Intervention Group. To measure the extent to which individuals in the Intervention Group actually used their computer and the Internet, participants in this group were asked at both the four-month and at the twelve-month follow-up moments to indicate how many hours per week they had used the computer and the Internet in the period prior to answering the questions. We chose to use this subjective indication of computer use over an objective measure (e.g. a log file) because of ethical reasons (e.g. participants may feel being controlled, which may in turn influence their computer use) and because it was not possible to control who was using the computer at any particular time (e.g. partners or grandchildren of the participants could also have access to the computer). Also, they were asked to indicate which computer and Internet applications they actually used. The total number of applications was used as a measure of the range of computer use.

Statistical analyses

Statistical analyses were performed with the SPSS v11.0 program series for Apple Macintosh. The alpha level was set at .05. To study demographical differences between the four groups at baseline, ANOVAs were conducted on the dependent variables age and level of education. Differences with respect to sex were analyzed using a Chi-square test.

Predictors of computer anxiety. Computer anxiety at baseline was predicted using multiple hierarchical regression analysis. Age, level of education and sex were entered in the first step. Interest in computers and the Internet was entered in the second step. The third step contained the factors 'use of everyday technology', anxiety, neuroticism, extraversion, mastery and perceived health status.

Intervention effect. A General Linear Model (GLM) with repeated measures analysis of variance was used to study the effect of the intervention. Analyses were conducted with group as between-subject variable (four levels: Intervention, Training/No intervention, No training/No intervention and Control Group) and time as within-subject variable (three levels: second baseline, four-month follow-up and twelve-months follow-up). Contrasts were defined to compare changes in performance over time (between the three measurements) of the four groups. Age, level of education and sex were used as covariates. We were especially interested in the interaction of time and group, as this interaction shows whether the groups differed from one another with respect to changes over time in the dependent variables.

The repeated measures analysis was also done with only the individuals in the Intervention Group to account for the extent of computer use. In these analyses the between-subject variable 'extent of computer use' had two levels: light and heavy. This variable was calculated by using a median split of the group, based on the number of hours per week participants reported they used their computers at the twelve-month follow-up moment. The median was 7.5 hours, so participants who reported using their computers 7 hours per week or less were labelled 'light users' and participants who reported using their computers 8 hours per week or more were designated 'heavy users'.

Relationship between Computer Anxiety and actual computer use. Hierarchical regression analysis was used to answer the question concerning the relationship between Computer Anxiety and actual computer use in the Intervention Group. Computer use (both the number of hours of computer use and the number of applications participants used) at the twelve-month follow-up moment was predicted in a model with age, level of education and sex entered in step one, and computer anxiety at baseline in step two. Computer anxiety at the twelve-month follow-up moment was predicted in a model with age, level of education and sex entered in the first step, computer anxiety at baseline in the second step and computer use (both the number of hours of computer use and the number of applications participants used) at the four-month follow-up moment in the third step.

All variables that were included in the analyses were first checked for normal distributions, missing values and outliers. No data transformation procedures were considered necessary for the analyses. All analyses were done with and without individual cases with extreme values and finally with replacement of extreme values by the highest values that were not labelled as extreme values (extreme values were defined as more than three times the interquartile range above the 75th or below the 25th percentiles). Also, all analyses were repeated with scores on the six subscales of the Computer Anxiety Scale as the dependent variable to gain insight into the domains of computer anxiety that are most important with respect to the predictors and the effect of our intervention.

Results

Baseline scores

At baseline the four groups did not differ with respect to age, sex and level of education. Baseline comparisons of participants who dropped out of the study at some point (n=36) with participants who completed all tests (n=198) showed differences in level of education (F(1, 229)=4.13, p=.04). Participants who dropped out had a lower educational level.

The baseline scores of each of the four groups on the Computer Anxiety Scale are presented in Table 1. At baseline, ANOVA showed significant differences between the groups (F(3,220) = 22.823, p < .01). Post hoc (Tukey) tests showed higher scores on the Computer Anxiety Scale of the Control Group compared with the scores of the Intervention Group (p < .01), the Training/No intervention Group (p < .01) and the No Training/No Intervention Group (p < .01). That is, participants who were interested in learning to use computers and the Internet showed lower Computer Anxiety scores than participants who were not interested. Baseline comparisons of the scores on the six subscales of the Computer Anxiety Scale showed similar results, with the exception of positive beliefs (no difference was found between the No training/No intervention Group and the Control Group), physical arousal (in addition to the differences between the Control Group and the three other groups a significant difference was found between the Training/No intervention Group and the No training/No intervention Group (p = .04): participants in the latter group had higher scores on the physical arousal subscale) and the negative beliefs subscales (no group differences were found).

Table 1 *Mean scores and standard deviations (SD) of the four groups on the Computer Anxiety Scale at baseline and both follow-up moments*

Group	N	Baseline	4 months	12 months
Intervention	56	9.40 (2.07)	9.12 (2.81)	8.81 (2.58)
Training/No intervention	41	10.03 (2.13)	9.96 (2.13)	10.21 (2.65)
No Training/No intervention	40	10.65 (1.94)	10.96 (2.31)	11.21 (2.28)
Control Group	30	13.02 (2.53)	13.28 (2.67)	13.23 (3.58)

Finally, participants who dropped out of the study at some point after baseline were compared with participants who completed all measurements. At baseline, participants who dropped out showed significantly lower levels of computer anxiety (t(222) =2.898, p<.01).

Predictors of computer anxiety at baseline

Results of the regression analysis showed that only the second and third step of the regression model explained significant additional proportions of variance of the baseline scores on the Computer Anxiety Scale. Step two, consisting of the factor “interest in computers and the Internet”, explained an additional 21.3% of the variance. The third step, containing the number of technological devices participants use, the anxiety scale of the SCL 90, both the neuroticism and the extraversion scale of the EPQ, the Mastery scale and perceived health status, explained an additional 5.4 % of the variance. Repeating the analyses for the six subscales showed that the second step, with interest in computers, explained significant additional proportions of variance of all subscales, ranging from 2.4% (of negative beliefs) to 23.2% (of affective feelings). The third step in the regression model explained a significant proportion of variance of the physical arousal subscale (6%).

Table 2 shows the unstandardized regression coefficients of the separate predictors in the final step of the regression model. Significant predictors were "interest in computers and the Internet" and the EPQ extraversion scale. Participants who were interested in learning to use computers and the Internet and participants with higher scores on the extraversion scale showed lower levels of computer anxiety at baseline. The regression coefficients of the subscales of the Computer Anxiety Scale showed that interest in computers and the Internet was a significant positive predictor of literacy, self-efficacy and affective feelings, and a significant negative predictor of physical arousal. The number of technological devices participants used was a significant positive predictor of literacy and level of education was a significant negative predictor of affective feelings. Finally, extraversion was found to be a significant positive predictor of affective feelings and a significant negative predictor of physical arousal.

Table 2 *Unstandardized regression coefficients (B) and standard errors (SE) in the final model for the baseline scores on the Computer Anxiety Scale*

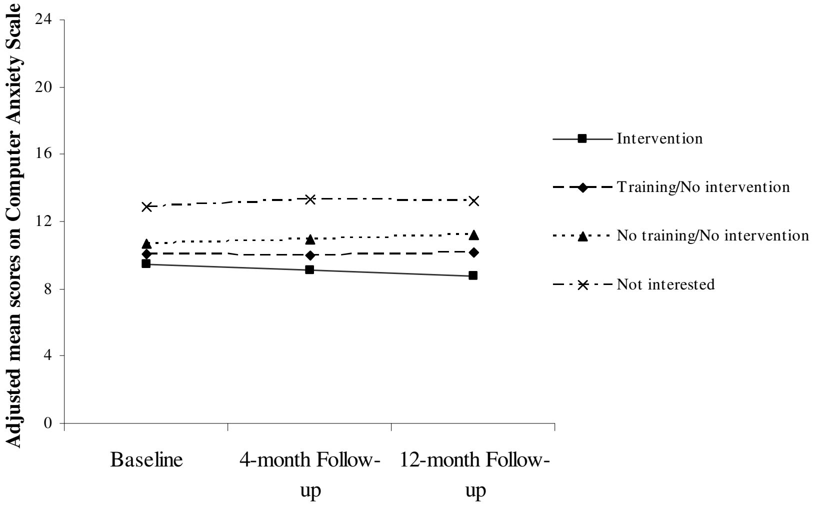
	B	SE
Age	0.03	0.06
Level of education	0.16	0.11
Sex	-0.39	0.34
Interest	-2.80 **	0.45
Number of devices	-0.12	0.06
SCL 90 Anxiety	0.02	0.06
EPQ Neuroticism	0.03	0.07
EPQ Extraversion	-0.14 *	0.06
Mastery	0.01	0.05
Perceived health	-0.17	0.25

Note * = p < .05, ** = p < .01

Effects of the intervention

GLM repeated measures ANOVA showed a statistically significant group by time interaction (F(6, 161) = 1.211, p = .02) for all time periods (that is between baseline and four-month follow-up, between four and twelve-month follow-ups and between baseline and twelve-month follow-up). Visual inspection of this interaction (Figure 1) suggested that the computer anxiety scores of the Intervention group slightly decreased over time, while the scores of the other groups did not. However, post hoc repeated measures ANOVA for each of the groups separately (using the Bonferroni method to correct for four extra analyses) showed no significant changes over time for any of the groups. Performing the same analysis with only light and heavy computer users in the Intervention Group also showed no significant effect of intervention.

Figure 1. *Mean scores of the four groups on the Computer Anxiety Scale, controlled for age, level of education and sex, at baseline and both follow-up moments.*



Repeating the analyses for the six subscales showed a significant group by time interaction for the physical arousal scale in the period between the four-month follow-up and the twelve month-follow up. As was the case with the Computer Anxiety Scale total score, post hoc analyses (with Bonferroni correction for the number of extra analyses) showed no significant changes of this scale for any of the groups in the same period.

Relationship between computer anxiety and computer use

With respect to the relationship between computer anxiety and actual computer use in the Intervention group, it was found that computer anxiety at baseline predicted a significant proportion of variance (17.4%) of the number of hours participants used their computer at the twelve-month follow-up moment after the proportion of variance was explained by age, level of education and sex. Computer anxiety was not found to predict the number of applications participants used at the twelve-months follow-up moment. Both measures of computer use (the number of hours of computer use and the number of applications participants used) at the four-month follow-up moment did not significantly predict computer anxiety at the twelve-month follow-up moment, when corrected for age, level of education, sex and computer anxiety at baseline.

Again, all analyses were repeated for the six subscales of the Computer Anxiety Scale, which were entered together in the final step of the analyses. It was found that the six subscales at baseline together significantly explained an additional 29.9% of the variance of the number of hours participants used their computer at the twelve-month follow-up. The regression coefficients showed that physical arousal was a significant negative predictor of both the number of hours of computer use and the number of applications participants used at the twelve-month follow-up. As was found in the analyses of the total score of the Computer Anxiety Scale, none of the scores on the subscales at the twelve-month follow-up moment was significantly predicted by both measures of computer use.

Discussion

The present study had three main questions concerning predictors of computer anxiety in a population of older adults with no active computer experience, the effect of using a computer for twelve months on anxiety level, and the relationship between computer anxiety and actual computer use. The findings, which will be discussed below in detail for each of the questions separately, have important implications for computer training programs and interventions related to computer anxiety in older adults.

With regard to the first question, i.e. predictors of computer anxiety in older adults with no active computer experience, the results of the regression analysis showed that participants with interest in using computers and higher extraversion scores showed lower levels of computer anxiety. The relationship between interest in computers and computer anxiety seems rather obvious; it was at least expected that individuals who did not wish to participate in our intervention would have higher levels of computer anxiety. Participants who were interested in computers reported higher levels of computer literacy, which is a remarkable finding since none of the individuals in this sample had any computer experience. This may be explained by the fact that the participants in the present study were to have no *active* computer experience and that individuals with an interest in using computers can be expected to have had some passive experience (gained by watching others, such as a partner, children or grandchildren using a computer, for instance). Also, participants were encouraged to answer all questions of the Computer Anxiety Scale. When this was impossible because of a lack of experience, participants were stimulated to answer the questions by imagining themselves using a computer. Possibly, even at this early stage, participants who wanted to learn to use a computer already felt more confident at the thought of using a computer.

Extraversion as a negative predictor of computer anxiety was also in line with the expectations. Extraverts tend to have a desire for excitement and activeness (Carver & Scheier, 1996), which can be linked to a desire to learn new things, for example using computers. A relationship between extraversion and computer anxiety, however, has not generally been found in earlier studies using younger participants. Chu and Spires (1991), for instance, found no significant relationship between extraversion and computer anxiety. This finding was also reported by Anthony et al. (2000) and Farina et al. (1991), who did find that neuroticism significantly predicted computer anxiety, a relationship we did not find in the present study. In other studies, neuroticism was also found to be related to computer anxiety. Sigurdsson (1991) for instance, found a relationship between neuroticism and computer anxiety; students who felt anxious about computers scored high on the EPQ-neuroticism scale. This suggests that extraversion, and not neuroticism, is a unique predictor of computer anxiety in older adults with no prior computer experience, which is in line with the abovementioned notion that extraverts tend to have a desire to learn new things. In other words, extraverts without computer experience may be quite eager to learn to use computers and therefore have lower levels of anxiety, which is actually reflected in our finding that extraverts showed more positive feelings toward computers. Once they have gained experience, their feelings toward computers are no longer entirely based on their desire for new experiences and may therefore no longer be very different from the feelings of less extravert individuals with the same amount of experience.

The present study focused exclusively on older adults who were selected on the basis of having no active computer experience at all, which has never been done before. Based on the findings in this large sample of older participants, it can be concluded that predictors of computer anxiety in older adults are not identical to those in younger adults. This conclusion is important with respect to computer programs aimed at older adults. Based on the present results, special attention should be paid to introvert older adults and to individuals with an aversion toward learning to use computers.

Some of the factors we did not find to significantly predict computer anxiety have been reported to be related to computer anxiety by other authors. Maurer (1994), for example, concluded in a review of the literature that there is some information on the relationship between personality variables and computer anxiety. A number of studies that he reported showed a relationship between control and computer anxiety, a relationship that was not significant in our sample. However, there are also studies reporting no relationship between control and computer anxiety (Crable, Brodzinski, Scherer, & Jones, 1994). The fact that we found that perceived control was not related to computer anxiety may be explained by the lack of experience of our participants. Individuals who do not have any experience with computers probably cannot relate their level of control to actual computer use because they have not experienced their control over a computer.

It was anticipated that participants with higher levels of anxiety would show more computer anxiety, but this was not supported by our data. In earlier studies, relationships between computer anxiety and several other types of anxiety were found. For example, Farina et al. (1991) found both anxiety towards mathematics and trait anxiety to be significant positive predictors of computer anxiety. Both Rosen and Maguire (1990) in their meta-analysis and Maurer (1994) in his literature review concluded that math anxiety and computer anxiety are related. Besides math anxiety, Rosen and Maguire also found that computer anxiety was related to state, trait and test anxiety. However, they conclude that these relationships with other types of anxiety rarely account for more than 10% of the variance of computer anxiety.

Other variables included as predictors in the model that did not significantly predict computer anxiety were age, level of education, sex, the number of technological devices participants use, and perceived health status. As was observed by both Chua et al. (1999) and by Maurer (1994), significant effects of age were generally only found in studies with wide age ranges, while our range covered only ten years, and many studies also found no significant effect of sex either. Level of education has not been studied very extensively in the context of computer anxiety, as is the case with the use of everyday technology and perceived health status.

The second question of this study concerned the effect of acquiring computer skills and the subsequent use of computer and Internet services on computer anxiety. It was expected that computer anxiety levels of participants in the Intervention group would decrease as a result of this intervention, but none of the four groups in the study significantly changed with respect to computer anxiety. In other words, levels of computer anxiety in older adults who had never used a computer before did not change as a result of using a computer and the Internet for a one-year period.

Because of the controlled and randomized design of our study and by using a large sample of participants, we were able to conclude that computer training as well as using a computer and the Internet for twelve months is not an effective strategy for reducing computer anxiety in older adults. Therefore, we believe it is not worthwhile applying this strategy on a large scale. Furthermore, future research should aim at developing other ways to change levels of computer anxiety, especially for older adults. This implication will be discussed in more detail below.

Positive effects of computer anxiety programs were found in some earlier studies that also focused on possible intervention programs to reduce computer anxiety (Reznich, 1996; Rosen, Sears, & Weil, 1993). The first and most important explanation of a lack of intervention effect in our study is the fact that the intervention was not especially designed to reduce computer anxiety. The intervention was actually aimed at stimulating older adults to use a computer and the Internet with as little divergence as possible from independent computer use by older adults in the normal population. For instance, it is possible that participants, in spite of the availability of a helpdesk, not only gained positive experiences but also some negative experiences. Moreover, Chu and Spires (1991) found that computer courses to reduce computer anxiety may only be useful for some factors of anxiety and for individuals with certain cognitive styles (intuitive styles in this case). It is possible in this context that the mere use of computers is not an appropriate strategy for reducing computer anxiety in a population of healthy older adults with no prior computer experience. Another explanation is the low level of computer anxiety in the Intervention Group. At baseline, the mean total score on the Computer Anxiety Scale was 9.40, which is not very different from the score in a "technology smart" sample representative of the Dutch population, which was 9.99 (Beckers et al., 2002). So, possibly there was a floor effect and participants could not decrease any further with respect to their computer anxiety scores as a result of normal computer use.

The third and final question of the present study concerned the relationship between computer anxiety and the actual use of computers in a population of novice older computer users. Analyses showed that computer anxiety at baseline predicted the extent of computer use twelve months later, but that the extent of computer use did not change the amount of computer anxiety. That is, computer anxiety appears to determine the extent of use, and not the other way around.

This result supports the finding that gaining computer experience does not change the level of computer anxiety. Therefore, in intervention programs that aim at reducing computer anxiety, the mere motivation of participants to use a computer is not sufficient. Consequently, future research should study other types of intervention strategies to address computer anxiety. For instance, there may be a role for psycho education here. It has been suggested for example, that the way people relate the requirements of (computer)technology to their own capacities (Hone, Graham, Maguire, Baber, & Johnson, 1998; Morris & Venkatesh, 2000) may prevent them from using this technology. Therefore, education that aims at reducing such psychological obstacles that older adults face when adopting new technologies may be a useful strategy.

The fact that computer anxiety only predicts the hours of computer use and not the number of applications may be explained by the fact that all participants in the Intervention group used only a few applications (a mean number of 2.7 applications in the light user group compared with 3.4 in the heavy user group) as they were novice computer users.

In summary, in a population of older adults without any computer experience, interest in computers and extraversion are significant negative predictors of computer anxiety. These factors should be accounted for in intervention programs to reduce or prevent computer anxiety. Because of the differences between predictors in older and younger adults, programs specifically tailored to the needs of older adults may be required. More research should therefore be aimed at identifying predictors of computer anxiety in other older populations as well (for instance, older people with computer experience). With respect to interventions to reduce computer anxiety, the present study showed that encouraging people to use computers and support them in this is not an effective strategy. Moreover, more extensive use of computers does not result in decreases in computer anxiety levels. Therefore, other solutions should be focused on and future research may study possibilities such as removing psychological barriers older adults experience (psycho education) or designing solutions that take older adults' capacities into account.

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Chapter 9

Risk of upper limb complaints due to computer use in older persons: A randomized intervention study

Submitted for publication

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Abstract

Older people may have a higher risk of developing arm pain (repetitive strain injury or RSI) when interacting with a computer interface, due to age-related changes in upper limb tissues and in the programming and co-ordination of the upper limb movements. Using a randomized controlled design, we studied whether the twelve-month use of a standard computer for leisure purposes would promote complaints of upper limb pain or functional limitations in novice computer users. Participants in this study were aged between 64 and 75 and received standard training in computer use and Internet services (web browsing, e-mail). Next, they were randomly assigned to the Intervention Group (n=62), whose members received a personal computer and fast Internet access at their homes, or a No Intervention control group, whose members refrained from further computer use during the study period. Participants were screened at baseline (M0) and after 12 months (M12) using the symptom and functional status scale (SFS) for upper limb complaints and the Short Form-36 (SF-36) scales for general health, physical and mental health, and pain. Mean scores on these scales did not differ between groups, both on M0 and M12 (all p>.05), and no differential change in the scores was found as a result of the intervention. Therefore it was concluded that prolonged, self-paced use of a standard computer interface does not promote upper limb complaints or reduce functional health in older adults.

In Western societies the personal computer has become an ubiquitous technology, both at home and in the workplace. Today, many individuals use a computer on a daily basis. Everyday computer activities are generally characterized by repetitive upper limb movements and a relatively fixed bodily position (Anonymous, 2004). Intensive interaction with a computer terminal interface, using a standard keyboard and a mouse, has been related to a complex of complaints related to the hand, arm and shoulder, often referred to as 'repetitive strain injury' (RSI), or sometimes as 'cumulative trauma disorder', 'non-specific work-related upper limb disorder' or 'repetitive strain disorder' (Helliwell & Taylor, 2004). This pain syndrome of the upper limb consists of protracted complaints of the hand, arm or shoulder, leading to functional impairment that is difficult to treat (Bongers, de Vet, & Blatter, 2002). Although the exact cause of RSI is still unknown, risk factors have been identified in epidemiological studies. Prolonged exposure to repetitive movements and less than optimal ergonomic conditions have been shown to increase risk, while secondary factors like working under time pressure and lack of autonomy and social support in the workplace can increase the frequency and severity of complaints (Bongers, 2002). Little is known, however, about the relative contribution of each risk factor and any possible synergistic effect.

Exact prevalence figures of RSI are unavailable, in part due to a lack of valid working definitions of RSI as a diagnostic entity (Gezondheidsraad, 2000), but in a recent Dutch population survey RSI complaints were reported by 20–40 percent of the working population. Complaints are more prevalent in females and older workers (Gezondheidsraad, 2000), but dedicated information about non-working older computer users is lacking. Furthermore, all studies done in this area so far have been observational in nature. No systematic prospective studies of computer users have been done to study RSI in a controlled fashion.

This lack of knowledge could be particularly harmful for older individuals, for it can be argued that people over 65 may be at risk of developing such complaints. Firstly, hand function deteriorates with age due to age-related degenerative changes in the musculoskeletal, nervous and vascular system (Carmeli, Patish, & Coleman, 2003). Besides this general deterioration, hand function in the elderly can be impaired by specific pathological conditions, like osteoporosis, osteoarthritis, or rheumatic arthritis (Carmeli et al., 2003; Gallagher, Verma, & Mossey, 2000). Secondly, recent insights into neural control of movements and muscle stiffness regulation provide further arguments for the older population being more at risk. For instance, the neuromotor noise theory explains why fine, coordinated distal movements require strong signals from the brain to the muscular system (Kail, 1997). This signal can be disturbed by different types of task-irrelevant neural activity. Such neural 'noise' can be generated by different sources, e.g. sensory input, parallel activity in adjacent cognitive networks ('double tasks'), or mood related brain centres (Van Gemmert & Van Galen, 1997). In order to improve the signal-to-noise ratio, the brain will suppress excess noise by stiffening the muscular system. For instance, it has been shown that increasing time pressure and task difficulty will cause enhancement of muscular tone (Bloemsaat, Ruijgrok, & Van Galen, 2004). This mechanism appears to be a normal adaptive response to "noisy" circumstances, e.g. reflected in the deterioration of handwriting when under time pressure. Recently it has been demonstrated that the aforementioned risk factors for RSI-like symptoms can be predicted by the neuromotor noise theory. It can be argued that an older brain will produce a less strong motor signal, is less able to suppress neural noise, and will intrinsically produce more noise (Cerella & Hale, 1994). Finally, evidence of age-related changes that may cause an unfavorable signal-to-noise ratio in the brain, thereby decreasing hand function, also comes from patient studies, e.g. into multiple sclerosis (Kail, 1997) and stroke (McCrea & Eng, 2005).

Thus, while individuals over 65 are adapting fast to the societal trend towards extensive use of computer-based technologies and services, it is unclear whether the potential benefit of leisure-time computer usage by older adults may be limited due to the risk of RSI. Intervention programs aimed at familiarization of older persons with the use of computer-based technologies may produce upper limb impairment as an unwanted side effect.

The present study set out to investigate if older computer users actually develop complaints and functional limitations of the upper limb in the course of a one-year computer and Internet training program. Apart from the use of a specific RSI-questionnaire, measures of general health were included in this study because upper limb bodily pain may be related to a reduction in overall health status in both younger and older individuals (Daffner *et al.*, 2003). Participants were interested in computer use for leisure and educational purposes, but had no prior computer experience. The study was part of a controlled intervention into the effects of computer and Internet usage by older adults on cognitive functioning and quality of life (Slegers, van Boxtel, & Jolles, subm).

Methods

For information about the participants and the procedure of the intervention study, see Chapter 3. For the purpose of this paper, baseline and twelve-month follow-up data were used of the Intervention Group and the Training/No intervention group. Follow-up data were available for 60 and 49 participants in both groups respectively. Data for fourteen participants were not available for several reasons: health problems (n = 2), time constraints (n = 2), private problems (n = 2), disappointment in randomization results (n = 2), death of partner (n = 1), moving (n = 1), no reason (n = 1). Two participants could not be reached for an appointment and one participant died. Five participants did not return their questionnaire even after repeated requests, leaving 57 and 47 participants in the Intervention and No Intervention groups with complete data.

Measurements

A standard questionnaire was completed at the start (M0) and the end (M12) of the study. It contained questions about demographical characteristics (e.g. educational level, marital status), health status and psychological and general wellbeing. At M12 information was collected about the total amount of time (hours per week) devoted to computer and Internet usage. A standard battery of cognitive tests was given at M0 and M12 to assess cognitive ability used in the main study. Results of this assessment are not discussed in this paper.

Specific measures. The Short Form-36 (SF-36) scale (McHorney, Ware, & Raczek, 1993) was used at both M0 and M12 to assess the general wellbeing of the participants. The scales for general health, physical functioning, mental health and bodily pain were used in this study. All scores refer to health complaints that were experienced in the four weeks preceding the testing. Scores on the SF-36 scales range between 100 (optimal) and 0 (worst).

Complaints about and functional impairment of the upper limb were measured with the symptom and functional status scale (SFS), a well-validated instrument that was originally developed for the assessment of upper limb pain, specifically the carpal tunnel syndrome (Levine *et al.*, 1993). It consists of eleven symptom items (e.g. 'How long, on average, does an episode of pain last during the daytime?') and eight functional impairment items (e.g. difficulties with writing), measured on five-point scales, with reference to the two weeks prior to testing. Domain scores for symptom severity and functional status were computed by taking the average of the items in each category. Thus the range of scores was between 1 (no complaint/impairment) to 5 (maximum severity of complaint/impairment).

Statistical analyses

Demographical data in both groups were compared with unpaired *t*-tests (age and educational level), or a Chi-square test (sex). All outcome measures failed a formal test of normality (Kolmogorov-Smirnov test) due to skewed distributions. Group differences on questionnaire data were tested with non-parametric Mann-Whitney *U* tests. Next, overall within-group changes on the health scales were tested using the Wilcoxon signed rank test for two related samples. Finally, M12-M0 difference scores were calculated for all SF-36 and SFS scales, which were again tested for group differences with Mann-Whitney *U* tests. All analyses were performed with the SPSS Program Series, v11.02 for Apple Macintosh, using an alpha level of .05.

Results

Participants in both study groups did not differ with respect to demographical background, i.e. age, sex or educational level (Table 1). At the twelve-month follow-up moment, participants in the Intervention group reported an average computer use of 8.3 (SD=6.2) hours per week. In total 6.5 hours (SD=5.6) per week was spent on Internet-related activities (web surfing, e-mail).

Mean scores on the four SF-36 and two SFS subscales did not differ between groups at baseline or 12 month follow-up (all $Z > -1.17$, $p > .05$). Pre- and post-intervention assessments on the SF-36 health scales showed a trend towards a more unfavorable health status in both groups combined after twelve months, more specifically with respect to general health (Z=-3.69, p<.001), physical health (Z=-2.30, p=.021) and bodily pain (Z=-3.84, p<.001). No differences were found between the M0 and M12 assessments on the SF-36 mental health scale and both SFS scales. Furthermore, when both groups were compared with respect to pre- to post-intervention changes on health scales, no differences were observed (all Z > -1.94, p>.05), indicating that there was no intervention-related differential change over time in general health, functional status or upper limb complaints.

Table 1. *Descriptive data for demographical variables, raw questionnaire measures and M12 (12 month follow-up) minus M0 (baseline) difference scores in both study groups. The male/female ratio was 25/32 and 21/26 in the Intervention and No Intervention groups respectively.*

	Intervention		No Intervention	
	Mean	SD	Mean	SD
Age	69.0	2,7	69.1	2.8
Educational Level	3.7	1.5	3.8	1.8
SF-36: General Health M0	70	14	73	12
SF-36: General Health M12	68	16	66	15
SF-36: Physical Functioning M0	86	14	86	13
SF-36: Physical Functioning M12	84	13	82	20
SF-36: Mental Health M0	80	14	80	14
SF-36: Mental Health M12	79	14	79	15
SF-36: Bodily Pain M0	89	16	90	15
SF-36: Bodily Pain M12	82	22	81	21
SFS: Functional Status M0	1.13	.35	1.12	.23
SFS: Functional Status M12	1.10	.22	1.10	.26
SFS: Symptom Severity M0	1.21	.45	1.22	.59
SFS: Symptom Severity M12	1.16	.36	1.19	.36
SF-36: General Health M12-M0	-2.89	12.10	-6.49	11.08
SF-36: Physical Functioning M12-M0	-2.28	11.77	-4.89	16.45
SF-36: Mental Health M12-M0	-.98	15.27	.26	10.44
SF-36: Bodily Pain M12-M0	-6.66	19.64	-9.16	19.52
SFS: Functional Status M12-M0	-.03	.35	-.03	.31
SFS: Symptom Severity M12-M0	-.02	.42	-.05	.60

Note SF-36 = Short Form-36 scale; SFS = symptom and functional status scale. No group differences were apparent on demographical variables with t-tests (Age, Educational level) or sex (Chi-square test). Mean SF-36 and SFS scores on separate test occasions and SF-36 and SFS difference scores over time were comparable for both groups (Mann-Whitney U test).

Discussion

In this study we tested whether the prolonged use of a standard computer interface puts older novice users at risk of poorer functional health and upper extremity complaints. To the best of our knowledge, this is the first randomized study into the effects of computer and Internet use on long-term functional status. A significant trend towards a poorer health status was apparent in both groups on the SF-36 subscales, including the bodily pain subscale. However, no indication was found that participants who were part of the Intervention group were at greater risk as regards the development of health complaints or functional impairment of the upper limb than participants in the control group.

It was remarkable that three out of four SF-36 measures showed a decrease over twelve months, which was unrelated to group membership. The SF-36 is a reliable instrument, known to be sensitive to even small age cohort differences (Van der Zee & Sanderman, 1993), but it remains rather unclear why the increase in reported bodily pain, in particular, occurred in this relatively short interval. The absence of differences between the two groups in reported health complaints may be a reflection of the lack of sufficient risk factors relating to developing RSI-like symptoms. Firstly, although the participants were well-motivated computer users, the mean time spent on computer related activities in the Intervention group was limited to 8.3 hours. This is, of course, much lower than the exposure of professional workers who use computers on a daily basis (Smulders & van den Bossche, 2004) but is still comparable to the average use in this age group of 7.7 hours (2002-2004) reported in a recent Dutch survey (Statistics Netherlands CBS, 2005). Secondly, it has been found that adverse psychological factors, including work-related stress, may add to the effect of repetitive movements of the arms and wrists in the etiology of upper limb complaints (Macfarlane, Hunt, & Silman, 2000). Since our participants used the computer mainly for personal goals, often related to leisure-time activities, this is another reason why the study group may have a lower risk of RSI-like complaints than those who are professionally active computer users. Thirdly, unfavorable ergonomic conditions, such as prolonged fixed body postures, which are common in working environments in the presence of time pressure, are also less likely to occur in a home situation. Still, the question remains as to whether older users who engage more intensively in computer-related activities, or who continue such activities for a longer period of time, may develop upper limb complaints at a later stage.

There are some methodological limitations in this study. First, we did not choose to do a specific diagnostic workup to detect functional impairments of the upper limb in accordance with clinical standards. It was felt at the start of this study that no comprehensive protocol was available to reliably test functional impairments of the forearm in the near normal range. Furthermore, application of a functional assessment test was considered to be prone to measurement bias as it would be difficult to test participants unaware of the actual rationale behind such tests. Our choice for the SFS scales to quantify upper limb pain may have limited the scope of possible upper limb complaints to the lower arm region, as no specific information was collected with this scale about complaints in higher regions of the upper extremity. Finally, no inventory was made of individual risk factors, such as ergonomics of the work place, subjective psychological distress, or underlying health disorders causing impairment of hand function.

In summary, older users of a standard computer interface with no prior computer experience were not at greater risk of a poorer general health or of more symptoms or functional impairment of the upper extremity after a twelve-month episode of average, self-paced use. We therefore concluded that during the execution of community programs aimed at engaging older persons in activities that include computer-based technology, generally speaking no special precautions are necessary to prevent upper limb complaints. However, when risk factors are evident in individual cases (e.g. osteoarthritis), specific preventive instructions could be given to prevent symptoms in the future, e.g. directed at maintaining an ergonomic posture, or by encouraging task pacing.

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Chapter 10

Computer use in the Maastricht Aging Study (MAAS): Determinants and the relationship with cognitive change

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Abstract

Cognitively challenging activities may support the mental abilities of older adults. The use of computers and the Internet provides divergent cognitive challenges to older persons, and in earlier studies positive effects of computer and Internet use were found on the quality of life. The present study addressed two questions regarding predictors of computer use and the relationship between computer use and changes in cognitive abilities over a six-year period in both younger (24-49 years) and older adults (above 50). Data were obtained from the Maastricht Aging Study, an ongoing longitudinal study into determinants of cognitive aging, involving a large sample of 1,823 participants who were followed for nine years. The results showed age-related differences in predictors of computer use: the only predictor in younger participants was level of education, while in older participants computer use was also predicted by age, sex and feelings of loneliness: men, younger participants, participants with higher levels of education and participants who feel less lonely are more inclined to use computers. Furthermore, protective effects of computer use were found for measures of selective attention and memory, in both older and younger participants. However, effect sizes were small, which implies that using computers had no practically relevant effect on cognitive change.

Cognitive abilities usually decline with age (Craik & Salthouse, 2000; van der Elst, van Boxtel, van Breukelen, & Jolles, 2005; van Hooren *et al.*, 2005). Several studies have suggested that engagement in cognitively challenging activities, such as reading books or newspapers, playing games, making crossword puzzles and listening to the radio or to music, is associated with maintenance or even improvement of cognitive skills and seems to protect against age-related decline of cognitive abilities (e.g. Bosma *et al.*, 2002; Christensen *et al.*, 1996; Hultsch, Herzog, Small, & Dixon, 1999; Verghese *et al.*, 2003; Wilson *et al.*, 2002).

The notion that it may be possible to improve cognitive functioning by promoting the participation of older persons in cognitively challenging activities is in line with the 'use it or lose it' notion (Swaab, 1991), which originally was based on neurobiological findings in animal models. In these studies it was found that the use of neurons and neuronal networks prolongs the efficiency of central nervous system (CNS) activity during life. When the notion of 'use it or lose it' is translated to a functional level, this would imply that mental stimulation may counteract the reduced efficiency of higher brain functions that comes with age. Evidence for this notion has been found in animal studies, which have shown that enriched environments, providing a stimulating and challenging habitat, are beneficial to the cognitive functioning of laboratory animals (e.g. Frick & Fernandez, 2003; Milgram, 2003). Also, such findings are consistent with the concepts of brain reserve and cognitive reserve, assuming that individuals with more complex neural networks or more elaborate cognitive strategies respectively, are better protected against symptom onset following brain damage (Robertson & Murre, 1999; Stern, 2002).

One way to engage in cognitively challenging activities is to use computers and the Internet (Jones & Bayen, 1998; McConatha, McConatha, & Dermigny, 1994; Mead, Batsakes, Fisk, & Mykityshyn, 1999). Moreover, using computers and the Internet may improve autonomy, because in order to use Internet services such as Web surfing or e-mail, many of the cognitive abilities that are also drawn upon for everyday functioning are recruited. For instance, long-term or procedural memory is required to reproduce the routines needed to use a computer program, e.g. to launch a Web browser, and to subsequently execute specific commands in that browser. Short-term memory, or working memory, may be activated to keep track of information already attended or to decide on the next action to take. Executive functions may come into play in order to sort necessary actions into the correct order. Visual search, information processing and attentional processes are required in order to find relevant cues, to evaluate which information on a web page is relevant within a given context, and to focus on those cues while ignoring or inhibiting irrelevant cues.

Because many of the aforementioned cognitive abilities needed for using the Internet decline with advancing age (e.g. Craik & Salthouse, 2000; Schaie, 1994), combined with the fact that information technologies are often unfamiliar to older adults, it can be expected that using the Internet provides a cognitive challenge to older people. Another reason why using the Internet may be a particularly suitable strategy to stimulate older adults to engage in cognitively challenging activities is that Internet based services may have special benefits for them with respect to autonomy and everyday functioning (e.g. Cody, Dunn, Hoppin, & Wendt, 1999; White *et al.*, 2002). For instance, the World Wide Web facilitates social interaction and communication (Czaja & Lee, 2001; Mead et al., 1999; Morrell, Mayhorn, & Bennett, 2000; Rogers & Fisk, 2000), and can provide means for entertainment and learning in the home (Czaja & Lee, 2001, 2003; Mead et al., 1999; White *et al.*, 1999). Also, the Internet provides access to information services (Czaja & Lee, 2003), and facilitates the execution of routine tasks (e.g. banking and shopping) (Bouchard Ryan & Heaven, 1986; Czaja, Guerrier, Nair, & Landauer, 1993; Rogers & Fisk, 2000). Finally, it has been argued that computer use can improve self-esteem and satisfaction with life (Jones & Bayen, 1998; Lawhon, Ennis, & Lawhon, 1996; Mead et al., 1999; Sherer, 1996). Because of these benefits, using computers and the Internet may be intrinsically rewarding for older adults, which may therefore motivate them to engage in this cognitively challenging activity.

Very few attempts have actually been made to study the impact of computer and Internet use on cognitive abilities. Several broader studies showed that psychosocial measures, such as self-confidence, loneliness, social interaction, satisfaction with life and depression, improved as a result of learning to use computers and the Internet (e.g. Cody et al., 1999; White et al., 2002). A limited number of studies have actually focused on the impact of computer and Internet use on cognitive functioning as the primary outcome. McConatha, McConatha and Dermigny (1994) showed that, in a small sample (N=14) of long-term care residents aged between 59 and 89, the score in the Mini-Mental State Examination (MMSE; a broad omnibus test of cognitive function), Activities of Daily Living (ADL), and depression scores improved after using an on-line computer service for six months. This service consisted of e-mail, access to a digital encyclopedia, bulletin boards, games and other educational and recreational applications. Comparable results were found in a subsequent study, where 29 nursing home residents, aged 50 and older, were divided into a computer training group and a control group (McConatha, McConatha, Deaner, & Dermigny, 1995). Groups were matched in terms of ability to take care of daily needs, cognitive functioning and depression level. Participants in the training group used the same on-line computer service as had been used in the previous study while participants in the control group participated in regular nursing home recreational and educational activities. After six months of using the computer service, participants in the computer-training group improved on the MMSE, ADL and depression scores, while the control group remained unchanged. In sum, several sources of largely circumstantial evidence indicate that learning to use a computer and the Internet in later life may have beneficial effects on the cognitive ability and life quality of older individuals.

Because of this small number of attempts to study the impact of computer use on cognitive aging, we studied this impact in a large group of older individuals (N = 236) in a controlled randomized design for a reasonably long period of time: twelve months (Slegers, van Boxtel, & Jolles, submitted). In this study, no clear effects of learning to use computers and the Internet and the subsequent use of these facilities at home for a twelve-month period were found on several domains of cognitive abilities in healthy older adults. These participants, who were randomly assigned to an Intervention group, were compared with three control groups to account for effects of intervention, computer training and interest in computers and the Internet. It was concluded that using a computer for twelve months was not an efficient strategy to protect community-dwelling older adults from age-related cognitive decline. Still, it could be argued that such effects may emerge only after longer follow-up intervals, with larger between-individual variation in the rate of change. No knowledge is currently available on the effect of longer (i.e. a few years) self-initiated computer use on cognitive functions. When positive effects of long-term computer use on cognitive abilities can be demonstrated, then the promotion of computer use to prevent people from age-related cognitive decline may still be an effective intervention. On the other hand, when a long-term effect of computer use on cognitive abilities is not to be expected, as was found with respect to a twelve-month period, such an advice is not evidence-based.

The first question of the present study considered predictors of computer use in both younger and older adults. As was explained above, computer use potentially has some very promising benefits for older adults. Therefore, it is important to stimulate older adults to start using computers. In this respect, knowledge about factors that determine whether individuals are inclined to use computers or not is important to aim at especially those individuals who tend not to use computers. For this purpose we were interested in sociodemographic measures of age, sex and level of education and several measures of autonomous functioning as possible determinants of computer use. With respect to the latter, two measures of functional ability, physical and mental functioning, were included. A measure of health status is relevant in this regard because computer and Internet services are especially interesting for individuals who are restricted in their mobility because of health problems. Furthermore, problems with mental health, such as mood problems, may cause individuals to lack initiative to engage in (new) activities that may actually be beneficial to them. Also, a measure of perceived cognitive problems was included. This measure is important in this context because people with low self-efficacy in, for instance, the cognitive domain, have low aspirations (Bandura, 1989) and may therefore be less inclined to start new activities such as using a computer. Finally, two measures of quality of life were included to account for peoples' loneliness and general life satisfaction.

The second aim of this study was to determine the relationship between computer use and changes in cognitive functioning, in order to test the abovementioned notion that engagement in cognitively challenging activities for a long period is associated with maintenance or even improvement of cognitive skills. For this purpose, we used a number of cognitive measures that represent a broad domain of cognitive ability (i.e., verbal memory, speed of information processing, attention, psychomotor ability and cognitive flexibility).

We investigated predictors of computer use and the relationship between computer use and cognitive functioning for both younger (up to 50 years) and older individuals (50 years and older) who were administered a questionnaire including several questions about computer and Internet use. The questionnaire also included items on the use of computer and Internet applications and some statements on the impact of computer use, so we were also able to study age-related differences with respect to these items.

For this study, data from the Maastricht Aging Study (MAAS) were used. MAAS is a large population study involving 1,823 healthy participants aged 24 to 81 years at the start. The major aim of this longitudinal study concerns biological, medical and psychosocial predictors of cognitive aging. For an extensive overview of the aim, design and population characteristics, see Jolles, Houx, van Boxtel and Ponds (1995). By using data from MAAS, it was possible to study computer use and it's predictors on a large scale. Also, because cognitive abilities were measured at several occasions, we were able to causally study the relationship between computer use and changes in cognitive functioning. To our knowledge, this has not been done before on such a large scale and with repeated measurements within the same population.

Of interest to the current study were the 6-year and 9-year follow-up measurements of MAAS. The predictors of computer use were studied cross-sectionally at the nine-year follow-up moment. Furthermore, the relationship between computer use and changes in cognitive functioning were studied retrospectively by calculating whether the participants had already been using computers at earlier occasions in this study. We were therefore able to use data from the baseline and second follow-up (six years later) test administrations, that included a neuropsychological test battery. These data were used to test whether computer use at baseline predicted the performance level on cognitive tests six years later.

Methods

Participants and procedure

Participants in this study were derived from the Maastricht Aging Study (MAAS). These participants were randomly recruited from a patient register of 15 collaborating general practitioners in the south of the Netherlands. At the moment of inclusion, they were between 24 and 81 years of age. Exclusion criteria were medical conditions known to interfere with normal cognitive functioning and participants were to have a score of 24 or higher on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). The study sample was stratified with respect to age (12 groups: 25 +/- 1, 30 +/-1, 35 +/-1, ..., 80+/-1 years), sex and level of occupational attainment (two levels). Between 1993 and 1995, 1,823 people were assessed with respect to both cognitive and physical measures. Three follow-up assessments took place after three, six and nine years. At each follow-up, all participants were administered several questionnaires. Participants of 50 years and older underwent a neuropsychological assessment at the first and second follow-ups. The younger participants were administered this test battery only at the second follow-up. Because of this discrepancy in follow-up frequencies between participants younger and older than 50 years at baseline, collapsing the data of these two groups is not viable due to differences in procedural learning effects. Therefore, the division between young and old adults was made at 50 years. Moreover, the proportion of computer users in this group of older adults aged 50 and older is reasonably high. When the division between young and old adults would have been placed at a higher age, 65 years for instance, this proportion is too small (n = 6) to properly analyse age differences.

The nine-year follow-up consisted of the administration of a questionnaire only, that included the questions about computer use. In total, data of 1,349 (74%) participants were collected at the nine-year follow-up. A MAAS staff member contacted non-compliant individuals or a proxy informant by telephone to inquire about reasons to leave the study. These 475 drop-outs did not return because they had died (n = 178), for medical reasons (n = 62), refusal (due to e.g. no interest, lack of time, experience burden, etc.) (n = 134), or were considered to have yielded unreliable test results on a previous occasion (n = 5). Ninety-six participants could not be reached or gave no reason for dropping out.

Measures

Questions on computer use. At the nine-year follow-up, the questionnaire included a custom question module on computer use. Participants were asked whether they use a computer and when this was the case to indicate the year they started doing this. This indication made it possible to calculate the number of years that participants had been using computers and also whether they had been using a computer at baseline already. Other questions to assess computer use concerned the kind of computer applications that participants used, the way they learned to use a computer, their use of the Internet and some statements on the impact of computer use .

Predictors of computer use. Both sociodemographic variables and measures of subjective functioning were included to predict computer use. Age, sex and level of education were used as demographical indicators. Level of education was measured on an eight-point scale as used by Statistics Netherlands (de Bie, 1987). The scale ranges from primary education to higher vocational training and university degree.

The physical and the mental functioning components of the Short Form-36 (Ware, Kosinski, & Keller, 1994), a 36-item questionnaire on general health and quality of life, were included to measure functional status. Also, a question whether participants were in the past year hindered by problems with their memory or concentration as a measure of subjective cognitive functioning was used. This question was scored on a five-point scale, ranging from “not at all” to “a lot”. Finally, as indications of subjective wellbeing, the Loneliness Questionnaire (LQ) (De Jong-Gierveld & Kamphuis, 1986) and the Satisfaction With Life Scale (SWLS) (Pavot, Diener, Randall Colvin, & Sandvik, 1991) were included.

Computer use as a predictor of cognitive functioning. To study the relationship between computer use and cognitive performance, two dummy variables were created to predict cognitive performance at the six-year follow-up: “computer use at baseline” and “start with computer use after baseline”, using the participants who indicated not to use a computer at the nine-year follow-up as the reference group. Of the core cognitive tests that are used in MAAS, five tests were included in this study to represent the most important domains of cognitive functioning.

Cognitive measures. The Visual Verbal Learning Test (VVLT) (Brand & Jolles, 1985; van der Elst, van Boxtel, van Breukelen, & Jolles, 2005) was used to measure verbal memory. In this test, fifteen monosyllabic, low-associative words are successively presented. After the presentation, participants were asked to recall as many words as possible without any time or order constraint (immediate recall). This procedure was repeated five times. Twenty minutes after the recall of the fifth trial, the participants were once more asked to recall as many words as possible (delayed recall). The score in the first trial of the immediate recall, the sum of the scores in the first three trials and the delayed recall score were used for this study.

The Letter-Digit Substitution Test (LDST) (van der Elst, van Boxtel, van Breukelen, & Jolles, in press) was used to measure the speed of processing general information. A code is provided at the top of a sheet of paper that couples the numbers 1 to 9 with random letters. Participants were asked to fill in on the rest of the sheet as many as possible corresponding numbers in boxes that contained only letters in 90 seconds.

The Concept Shifting Test (CST) (Vink & Jolles, 1985) was used to measure cognitive flexibility. This test consists of three sheets of paper with 16 small circles that are grouped in a larger circle. On the first sheet, numbers appear in the small circles in a fixed random order. Participants were asked to cross out these numbers in the right order as fast as possible. On the second sheet, letters appear in the circles. On the third sheet, participants had to alternate between numbers and letters. The difference between the score for the third sheet and the mean of the scores for the first and second sheets was used as an estimate of the slowing due to the shifting between two concepts (numbers and letters), i.e. cognitive flexibility.

The Stroop Colour Word Test (SCWT) (Houx, Jolles, & Vreeling, 1993) was used as a measure of selective attention and susceptibility to interference. The test contains three cards displaying a hundred stimuli each: colour names, coloured patches and colour names printed in incongruously coloured ink. The time needed to read (first) or to name colours (second and third card) of each of the cards was recorded. The difference between the score for the third card and the mean of the scores for the first and second cards (the interference score) was used as a measure of the capacity to inhibit a habitual response (reading the word), which reflects selective attention.

To measure psychomotor speed, finally, the Motor Choice Reaction Time test (MCRT) (Houx & Jolles, 1993) was included. This test is administered with a six-button panel, containing one red button and five white buttons, laid out in a semicircle around the red button. The participants were asked to hold down the red button with the index finger of the preferred hand. As soon as one of the white buttons was lit, the participants were to release the red button and then press the lit button (or a button adjacent to it) as quickly as possible. After this, the red button had to be held down again. The MCRT involved three conditions. In the first condition (simple reaction time), only the upper white button was lit. In the second condition (choice reaction time), one of the three upper buttons was lit. In the third condition (incompatible choice reaction time), one of the three upper buttons was lit, however, the button immediately to the right of the lit button was to be pressed.

Two variables were of interest for the purposes of this study. Firstly, the difference between the median response times of the second and the first condition was used as an indication of response selection. Secondly, a measure of inhibition of a prepotent response (Kornblum, Hasbroucq, & Osman, 1990) was provided by taking the difference between the median times needed in the third and the second condition.

Statistical analyses

Statistical analyses were performed with SPSS version 11 for Apple Macintosh. Alpha level was set to .05. To exploratory study differences between younger (up to 50 years) and older (50 years and above) participants with respect to the questions on computer use, both unpaired t-tests and Chi-square tests were performed.

Cross-sectional predictors of computer use. Logistic regression analyses were performed to predict computer use in both age groups. Also, linear regression analyses were performed to predict the number of years participants had been using computers in both age groups. Chronological age, level of education and sex were entered in the first step. In the second step, the physical and mental component of the RAND-36, hindrance of problems with remembering, memory and concentration, the Loneliness Questionnaire and the Satisfaction with Life Scale were included.

Predictors of longitudinal cognitive performance. Linear regression analyses were used to study the relationship between computer use and cognitive changes over a six year period. For all dependent variables, performance on the cognitive tests at the six-year follow-up, the same regression models were used. In the first step, age, sex and level of education were entered. In the second step, baseline performance on the particular cognitive test was entered. Finally, in the third step, the two dummy variables coding for "computer use at baseline" and "start to use computers after baseline" were included.

For all analyses two age groups were composed: the young group including the participants who were younger than 50 years at baseline, and the old group, including the participants who were 50 years or older at this time. Both the cross-sectional regression analyses and the longitudinal regression analyses were performed separately for each age group.

Results

A total of 1,323 participants of MAAS answered the question whether they used computers or not. Not all computer users indicated the year in which they started to use computers. We were able to reliably assess for 1,256 people if they already used computers at baseline. The cross-sectional comparisons and the regression analyses were performed with the complete set of available data. Comparisons concerning the duration of computer use and the longitudinal regression analyses were done with data of the 1,256 participants of whom the start date of computer use was available.

Age differences in computer use

Both at baseline ($\chi^2(1, N=1,256) = 189.87, p<.01$) and at the nine-year follow-up ($\chi^2(1, N=1,323) = 385.23, p<.01$), more participants in the younger group used a computer than in the older group (for the exact numbers and percentages, see Table 1). Also, in the younger group there were relatively more participants who started using a computer in the period between baseline and the nine-year follow-up ($\chi^2(1, N=1,256) = 47.95, p<.01$). In the group of computer users, participants in the younger age group had been using computers on average for a longer time (10.3 years) compared to participants in the older age group (7.2 years) ($t(750) = 5.39, p<.01$), and younger users also contacted more people and organizations (21.0) via e-mail (($t(621) = 3.65, p<.01$) than older users did (12.7). In the younger group of computer users, more participants (92.8%) had access to the Internet ($\chi^2(1, N=821) = 31.67, p<.01$) than in the older group (72.8%). No difference was found with respect to the number of hours per week participants reported to use the Internet (6.77 hours in the young group vs. 5.55 hours in the old group).

Table 1 *Number of participants who use a computer at baseline and at the nine-year Follow-up, by age (< 50 vs. 50⁺), sex and level of education (low vs. high)*

Baseline						
	young			old		
Level of education	male	female	total	male	female	total
low	26 (26.3%)	21 (19.9%)	47 (19.9%)	12 (7.3%)	4 (1.6%)	16 (4.0%)
high	165 (71.7%)	96 (49.0%)	261 (61.3%)	42 (35.3%)	7 (10.0%)	49 (25.9%)
total	191 (58.1%)	117 (35.3%)	308 (46.5%)	54 (19.0%)	11 (3.5%)	65 (10.9%)
Nine-year follow-up						
	young			old		
Level of education	male	female	total	male	female	total
low	82 (76.6%)	89 (62.7%)	171 (68.7%)	49 (28.5%)	40 (16.4%)	89 (21.4%)
high	242 (98.0%)	200 (93.0%)	442 (95.7%)	78 (62.4%)	39 (54.9%)	117 (59,7%)
total	324 (91.5%)	289 (81.0%)	613 (86.2%)	127 (42.8%)	79 (25.1%)	206 (33.7%)

Note The percentages in the table refer to the proportion of computer users in relation to the total number of participants in each cell

Some differences were found with respect to the way people learned to use computers. It was found that more younger (58.1%) than older (40.1%) users taught themselves to use a computer and that more older (36.2%) than younger (24.1%) users preferred a book to learn to use a computer. No differences were found between the percentages of younger and older users with respect to taking a computer course (50.7% vs. 51%) and to learning from friends or family (43.5% vs. 37.4%). Also, there were differences in the applications that younger and older participants indicated to use (see Table 2). More users in the older group indicated to use their computer to play games. Relatively more participants in the younger group used all other applications, except graphic applications, where no differences were found. More younger than older computer users also indicated to use the Internet for searching information about events, travel and opening hours, for reading news and for shopping. Again, in the older group of computer users, the proportion of participants who indicated to use the Internet for playing games was larger than in the younger group (see Table 2).

Table 2 *Percentages of participants in the young and old age groups that use each of the computer and Internet applications and differences between the groups*

	young	old	df	N	χ^2	sig.
Computer						
word processor	82.4	71.0	1	820	12.27	<0.01
Internet browser	83.5	61.4	1	820	44.22	<0.01
e-mail	80.8	68.6	1	820	13.18	<0.01
games	41.6	51.9	1	819	6.69	<0.01
calculating	33.6	20.4	1	819	12.76	<0.01
multimedia	26.1	14.1	1	819	12.56	<0.01
graphic	14.8	11.7	1	819	1.30	NS
Internet						
Searching information on:						
events	28.5	14.1	1	819	17.20	<0.01
travel/public transportation	53.5	43.7	1	819	5.95	0.02
health	24.1	18.9	1	819	2.38	NS
opening hours	19.2	7.8	1	819	14.86	<0.01
games	18.0	11.1	1	819	6.51	0.01
newsgroups	10.9	6.8	1	819	2.96	NS
chatting	8.0	4.4	1	819	3.08	NS
reading news	33.4	20.9	1	819	11.54	<0.01
shopping	20.2	10.7	1	819	9.60	<0.01

Finally, some age differences were found with respect to the statements on the impact of computer use (see Table 3). Older users agreed more (or disagreed less) with the statements that using computers and the Internet provides a possibility to train their brain, to deal with everyday problems, and to improve autonomy. On the other hand, they also found working with computers and the Internet more difficult than younger users.

Table 3 *Means (SD) of and differences between the young and old age groups with respect to their agreement with the statements on computer and Internet impact*

	young	old	df	t	sig
1. train your brain	3.23 (0.82)	3.49 (0.71)	809	-3.94	<0.01
2. dealing with everyday problems	2.71 (0.88)	2.91 (0.76)	808	-2.81	<0.01
3. autonomy	3.25 (0.89)	3.40 (0.81)	807	-2.22	0.03
4. dealing with other technologies	3.38 (0.78)	3.38 (0.83)	801	0.04	NS
5. quality of life	3.22 (0.92)	3.13 (1.00)	802	-1.11	NS
6. Internet is difficult	2.43 (0.94)	3.16 (0.93)	808	-9.55	<0.01
7. changed my life	2.67 (1.03)	2.61 (1.00)	805	0.79	NS
8. increase regular contacts	2.95 (1.06)	2.89 (0.99)	803	0.68	NS
9. meet new people	2.93 (1.04)	2.92 (0.93)	801	0.43	NS
10. not for me	1.84 (0.93)	1.95 (0.96)	804	-1.49	NS

Cross-sectional predictors of computer use

For both age groups, the first step in the logistic regression, including age, level of education and sex, analysis with computer use as the dependent variable predicted a significant percentage of the cases correctly (93.3% and 79.5% in the young and old age groups respectively). The next step including the subjective measures of autonomous functioning and wellbeing, did not add to the prediction of group membership in both age groups.

Table 4 shows the unstandardized regression coefficients of the separate predictors in the final step of the regression models for both age groups. In the younger group, only level of education significantly predicted computer use; participants with higher levels of education showed a higher tendency to use computers. In the older age group, next to age, sex and level of education, the score on the loneliness questionnaire significantly predicted computer use. That is, in this age group, participants who were younger and male, who had higher levels of education and who felt less lonely were more inclined to use computers.

Next to computer use, linear regression analyses were done to predict the number of years participants had been using computers. In both age groups, none of the two steps in the model explained significant proportions of variance. Also, in the final step of these regression models, not one of the separate predictors were found to significantly predict the number of years of computer use.

Table 4 *Unstandardized coefficients (B), standard errors (SE) and odds ratios (OR) in the final model for computer use at the nine-year follow-up*

young	B	S.E.	Wald	Sig.	OR
Age	-0.07	0.06	1.39	NS	0.94
Education	0.69	0.17	15.81	0.00	2.00
Sex	-0.48	0.46	1.13	NS	0.62
Physical functioning	0.02	0.04	0.26	NS	1.02
Mental functioning	0.04	0.04	1.32	NS	1.04
Loneliness	-0.02	0.04	0.27	NS	0.98
Satisfaction with life	0.00	0.04	0.00	NS	1.00
Memory/concentration	0.41	0.36	1.32	NS	1.51
old	B	S.E.	Wald	Sig.	OR
Age	-0.13	0.01	145.56	0.00	0.88
Education	0.65	0.06	105.43	0.00	1.91
Sex	-0.89	0.19	22.75	0.00	0.41
Physical functioning	0.02	0.01	1.77	NS	1.02
Mental functioning	-0.02	0.01	1.62	NS	0.98
Loneliness	-0.03	0.02	3.99	0.05	0.97
Satisfaction with life	0.02	0.02	0.71	NS	1.02
Memory/concentration	0.05	0.12	0.18	NS	1.05

Computer use as a predictor of longitudinal change in cognitive performance

For both age groups, the first step in the model, including age, sex and level of education, explained significant proportions of variance of all the cognitive measures (ranging from 7.3% to 17.3% in the younger group and 7.8% to 32.6% in the older group) except for the response selection measure of the MCRT. In general, lower performance was associated with higher age and lower level of education, and women tended to outperform men. The second step, baseline performance on the particular task, explained significant additional proportions of variance for all of the measures in both groups (ranging from 4.6% to 34.3% in the younger group and 4.8% to 33.2% in the older group). The final step in the model, including the two dummy variables of computer use, only explained additional variance in performance in the youngest age group on the SCWT interference score (0.6%) and on the first trial of the VVLT (1.0%).

Table 5 shows the unstandardized regression coefficients of the separate predictors in the final step of the regression models for both age groups. Computer use was a significant predictor of the SCWT interference score, computer users showed better scores, and of the first trial of the VVLT, again, computer users showed better scores, in the youngest age group. Participants who had started to use computers after the baseline assessment performance show better SCWT interference scores (both age groups), better scores on the first trial of the VVLT (in the older group only) and on the total score of the VVLT (in the older group only). The effect sizes of these significant regression coefficients (partial η^2) ranged from .007 to .012. That is, the proportion variance that was uniquely explained by computer use is 0.7 to 1.2%.

Table 5 *Unstandardized coefficients (B) and standard errors (SE) in the final model for each of the cognitive measures*

	LDST		CST		SCWT		VVLT trial 1		VVLT total		VVLT dr		MCRT rs		MCRT inhib.	
Young	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Age (years)	-0.06	0.03 *	0.14	0.04 **	0.12	0.05 **	-0.04	0.01 **	-0.07	0.02 **	-0.02	0.01	-0.19	0.17	1.03	0.24 **
Education (1-8)	0.31	0.14 *	-0.60	0.18 **	-0.65	0.24 **	0.11	0.05 *	0.41	0.13 **	0.18	0.06 **	0.06	0.86	-0.35	1.18
Sex	0.62	0.44	0.10	0.54	-0.97	0.75	0.20	0.16	0.81	0.38 *	0.56	0.18 **	2.79	2.64	2.88	3.65
Baseline score	0.86	0.03 **	0.28	0.04 **	0.57	0.03 **	0.43	0.05 **	0.54	0.04 **	0.50	0.04 **	0.19	0.04 **	0.46	0.04 **
PC use (yes/no)	0.39	0.77	-0.16	0.94	-3.16	1.28 *	0.72	0.27 **	1.14	0.64	0.00	0.30	-1.82	4.57	-7.40	6.27
start PC use (yes/no)	0.79	0.71	-0.32	0.87	-2.52	1.18 *	0.44	0.25	1.16	0.59	0.19	0.28	-4.37	4.23	-5.98	5.81
Old																
Age (years)	-0.19	0.03 **	0.27	0.08 **	0.55	0.10 **	-0.05	0.01 **	-0.13	0.03 **	-0.04	0.01 **	-0.47	0.29	1.08	0.48 *
Education (1-8)	0.36	0.15 **	-0.76	0.36 *	-0.42	0.44	0.19	0.05 **	0.42	0.13 **	0.14	0.07 *	1.21	1.29	-0.34	2.03
Sex	-0.59	0.48	2.53	1.16 *	-3.76	1.45 *	0.21	0.16	0.49	0.43	0.36	0.22	-3.28	4.28	-8.67	6.77
Baseline score	0.84	0.03 **	0.40	0.05 **	0.77	0.04 **	0.29	0.05 **	0.55	0.04 **	0.65	0.04 **	0.27	0.04 **	0.56	0.05 **
PC use (yes/no)	1.09	0.87	-1.98	2.09	-2.54	2.60	0.16	0.30	0.05	0.77	0.32	0.38	1.04	7.56	-9.62	11.91
start PC use (yes/no)	0.47	0.63	0.09	1.51	-3.70	1.88 *	0.47	0.21 *	1.21	0.55 *	0.44	0.27	5.09	5.49	-6.61	8.69

Note * = significant at $p < .05$, ** = significant at $p < .01$
PC use = computer use at baseline, start PC use = start with computer use after baseline
LDST = Letter-Digit Substitution Test, CST = Concept Shifting Test, SCWT = Stroop Colour Word Test, VVLT = Visual Verbal Learning Test, VVLT dr = Visual Verbal Learning Test delayed recall score, MCRT rs = Motor Choice Reaction Time test response selection, MCRT inhib = Motor Choice Reaction Time test inhibition score

Discussion

The two main questions of the present study concerned predictors of computer use in younger and older individuals and the relationship between computer use and changes in cognitive functions over a six-year period. Before discussing the results with respect to these questions, we first consider age-related differences in the use of computer and Internet applications, and participants' opinions about a number of computer and Internet-related statements.

The differences with respect to the actual use of computers were in line with the expectations, i.e. the proportion of younger participants using a computer was larger, younger computer users contacted a larger number of people through e-mail, and the proportion of computers users with access to the Internet was also larger in the younger group. While older adults used their computers as much as younger adults for Internet-related activities, some differences were found with respect to the applications that were used. Overall, both for computer and Internet applications, older adults tended to use their computers more for playing games than younger adults. All other applications were used by proportionally more of the younger adults. This may be explained by the fact that in the younger group probably more individuals use computers and the Internet for work or study-related activities compared with the older group.

The results of the computer statements showed that the older computers users agree more with the notion that computer use has a positive effect on autonomy and cognition-related issues. That is, they are more convinced of the notion that using computers and the Internet prevents people from cognitive decline and improves autonomy and everyday functioning. The difference between older and younger computer users with respect to this beneficial impact of computers and the Internet may be due to the fact that learning to use computers is very new to older adults and that this requires quite an investment, both in terms of time and effort. For younger users, on the other hand, computers and Internet more gradually have become a part of their everyday activities, for instance via school or work, and is much more essential for them. For older adults, on the other hand, using a computer is more special and provides more of an enrichment to their common activities and may thus be considered a means of assistance with everyday autonomy. Moreover, it may be speculated that this is one of the reasons for older adults to start using a computer, while younger users are more often forced to use computers for school or work related activities.

The first question in the present study was whether predictors of computer use differ with respect to age. It was found that in the older group, individuals who were younger, who were male, who had a higher level of education and who felt less lonely showed a higher tendency to start using computers. In younger people, only individuals with a higher level of education showed this higher tendency. These results demonstrate that for older adults there may be more factors involved that cause individuals to start using computers. That is, to motivate older adults to use computers, the factors age, sex, level of education and whether someone feels lonely need to be considered. Especially the negative relationship between feelings of loneliness and the use of computers is surprising, as computer and Internet facilities are of particular interest for people who feel lonely and who might increase their social network through online communication. A possible explanation for the relationship that was found in the present study is that people who use computers and the Internet feel less lonely as a result of using these facilities. Based on the present findings, campaigns aimed at stimulating older adults to use computers could be especially designed to appeal individuals who feel lonely. By taking the abovementioned predictors into account, older individuals who might not be inclined to start using a computer on their own initiative may be persuaded to do so. As a result these individuals may also profit from computer and Internet services that may support their autonomous functioning.

The second aim of the present research was to study the relationship between computer use and cognitive changes. The results showed that younger computer users, compared with younger non-users, showed better Stroop interference scores and better scores on the first trial of the VVLT, corrected for baseline test performance. The same analyses showed that older individuals who started to use computers in the six year period between baseline and follow-up show better Stroop interference scores, better scores on the first trial of the VVLT and better VVLT total scores. In younger adults, starting to use computers was related to better Stroop interference scores. With respect to the original question, this implies that computer use may indeed be related to some changes in cognitive abilities. More specifically, using computers appeared to protect individuals from declines in selective attention and memory. It has to be noted here though, that the size of this protective effect is very small, which will be discussed in more detail below.

The difference in the protective effect of computer use between younger and older adults is mainly that in younger adults effects of both the factor 'computer use' and of the factor 'starting to use computers' were found, while in older adults only effects of starting to use computers were found. This difference may be explained by the fact that the proportion of computer users at baseline in the older group is substantially lower (10.9%) than in the younger group (46.5%) and may therefore be a power-issue. Also, the increase in computer users between baseline and the nine-year follow-up (which reflects the number of participants who start to use computers), is much higher in the older group: more than three times as many older individuals at the nine-year follow-up use computers than at baseline, compared with almost twice as much individuals in the younger group. As a result of this, and because of the abovementioned fact of a lower proportion of computer users at baseline in the older group, the effect of the predictor "start to use a computer" may be larger than the effect of "computer use at baseline". As was mentioned above, the small size of the effects of the computer use dummies should be born in mind in the consideration of the differences in these effects between young and old participants. That is, some effects may be significant in young adults while they are not significant in old adults, in both groups the effect sizes are very small.

The finding that computer use is related to changes in cognitive abilities are not in line with the results of our intervention study, which showed no effects of twelve-month computer and Internet use on changes in cognitive abilities. The small number of studies who did found relationships between computer use and measures of cognition in intervention studies (McConatha et al., 1994; McConatha et al., 1995) used quite unspecific measures of cognitive ability when compared with those that were used in the present study so it may be difficult to compare these results with the current findings. The differences in findings between our earlier intervention study and the present findings may have several causes. First, the period of computer use of the two studies is different. It could be hypothesized that one year of computer use is not enough to cause changes in cognitive functioning, while six years of computer use, although small, does yield such changes.

Another difference regards the way participants initiated their computer use. In the present study, computer use was self-initiated, while in intervention studies participants respond to an advertisement or invitation and are provided with a computer. As a result, individuals may have differed in their motivation to use computers. However, when differences in motivation are reflected in differences in the amount of computer use, this could not be confirmed as the participants in the Intervention Group of our intervention study used the Internet with an average of 6.51 hours, compared with 6.77 hours of the young group and 5.55 hours of the older group in the present study.

A third and final explanation of the differences in findings concerns the number of participants, and thus the power of both studies to detect differential change. As intervention studies are quite intensive, both with respect to financial and time issues, the number of participants is usually much smaller than in population-based observational studies, such as MAAS. Because of the large number of participants in MAAS, the power to detect relatively small effects is quite high, while intervention studies are usually designed to detect medium sized effects. This is supported by the fact that the proportions of explained variance in the final step in the regression model, with computer use and starting to use computers as predictors, was quite small and only significant in the younger group. The effect sizes of computer use and starting to use computers in the final step of the model for both age groups were also too small to imply a practically relevant effect.

A limitation of longitudinal studies in general and therefore also of the present study concerns attrition. In this case, 26% of the participants who started with MAAS either dropped out of the study, or were unavailable for the nine-year follow-up. Differences in neuropsychological performance between dropouts and participants who stay in the study are a common finding in studies with a longitudinal design (e.g. Cooney, Schaie, & Willis, 1988). Also in MAAS one of the predictors of attrition between baseline and the three-year follow-up was found to be poorer performance on the baseline cognitive tests (van Beijsterveld *et al.*, 2002). As a result, the participants who were still available for follow-up after nine years, and whose computer use data are known, may represent a select group of the original participants, which may have biased the results towards smaller effect sizes. That is, as dropouts tended to perform worse on the neuropsychological tests at an earlier stage in the study, the attrition most likely will cause an underestimation of the differences between computer users and non-users.

In conclusion, the results of the present study show that predictors of computer use in older adults do not match those in younger adults. This implies that programs aimed at promoting computer use in older adults should account for these predictors. More specifically, such programs should aim at women, older and lower-educated individuals and individuals who feel lonely. Regarding the relationship between computer use and changes in cognitive abilities, we found a small protective effect of computer use on selective attention and memory processes in both younger and older adults. However, based on both the present study, using a very large group of participants representative of the normal population, and on earlier studies, including a controlled, randomized intervention study in a relatively large group of older adults, it seems likely that stimulating older adults to use computers and the Internet may yield only minor effect sizes. Therefore, we consider the promotion of computer use in order to boost cognitive functions not an effective strategy to pursue.

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Chapter 11

User preferences for web design compared: Are age-specific interface guidelines necessary?

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Abstract

Many guidelines exist for the design of user interfaces for older users that are primarily based on age-related limitations in perceptual, motor, and cognitive abilities. This study was designed to compare the preferences of older and younger users on several characteristics of web design and to compare these preferences with existing guidelines. Results showed that the web design preferences of older and younger users appear to be very similar, which supports the 'universal design' approach. User preferences largely corresponded to those incorporated into guidelines. However, the fact that some discrepancies between guidelines and preferences were found indicates that, in addition to user capabilities, user preferences should also be taken into account in web interface design.

Internet has a lot to offer for older adults in terms of autonomy support and quality of life improvement. First, it helps individuals to keep in touch with the outside world and to maintain social contacts, which is particularly essential for individuals with physical impairments (Czaja, 1996; Mead, Batsakes, Fisk, & Mykityshyn, 1999; Morrell, Mayhorn, & Bennett, 2000). Indeed, the use of Internet services has been shown to increase the perception of social support (Cody, Dunn, Hoppin, & Wendt, 1999; Morrell, 2002). Second, it provides users with access to relevant information, for instance, about health issues (Cody et al., 1999; Morrell et al., 2000) and hobbies (Czaja, 1996). Third, by providing services like home shopping and home banking, the Internet may facilitate instrumental activities of daily living, which are important for autonomous functioning (Czaja & Lee, 2003). Finally, there is evidence that Internet use may have psychological benefits, such as increased well-being and sense of control (Morrell, 2002).

Apart from these obvious advantages, in the past decade the ability to use information technology has become increasingly important in our daily lives. For instance, collecting money from a bank account has become virtually impossible in the Netherlands without using a cash machine as most banks are phasing out desk transactions. Furthermore, many computer-based assistive devices have become available which can support older adults in their daily routines, e.g. microwave ovens to prepare ready-made meals, computer systems providing reminders of medical schedules, etc.

A number of studies have drawn attention to the fact that older adults seem to experience problems when dealing with information technology or Internet services, such as web surfing and e-mail. Older adults need more time, are more error-prone, and need more steps to reach their goals (Czaja, Guerrier, Nair, & Landauer, 1993; Czaja & Sharit, 1997; Kelley & Charness, 1995; Mead, Spaulding, Sit, Meyer, & Walker, 1997; Mead, Jamieson, Rousseau, Sit, & Rogers, 1996; Walker, Millians, & Worden, 1996). Yet despite these encountered difficulties, older adults are able and willing to learn such new skills and appear to enjoy it as well (Czaja, 1996; Morrell et al., 2000; Rogers & Fisk, 2000).

In order to improve Internet 'performance' of older individuals, it is important to take into account age-related limitations when designing computer interfaces. Nowadays, the development of adequate guidelines for the design of computer interfaces and websites for older adults has become an important research area (Holt & Morrell, 2002; van Gerven, Paas, van Merrienboer, & Schmidt, 2000).

As a result of this, guidelines have become available for the design of user interfaces and, more specifically, web interfaces (e.g. Fleming, 1998; Nielsen, 1999). More recently, attention has been directed to the development of guidelines that specifically focus on interface design for older adults (Czaja & Lee, 2003; Echt, 2002; Holt & Morrell, 2002; Laux, 2001; Mead, Lamson, & Rogers, 2002). These guidelines are mainly based on age-related changes in perceptual, motor, and cognitive abilities that might cause older adults to experience more difficulties in using computers and the Internet. For instance, visual acuity and contrast sensitivity diminish with age, which causes a decreased ability to discern small details and colour hues of visual objects. Aiming movements become less accurate with age, which can interfere with mouse pointer movement towards targets such as hyperlinks or buttons. Furthermore, cognitive functions such as working memory and spatial memory are recruited in order to remember previously visited web pages and to keep track of the virtual orientation in cyberspace. Behavioral planning is needed to develop efficient strategies and attention resources are required in order to extract relevant information from the screen. As these cognitive functions tend to decline with age (Craik & Salthouse, 2000; Schaie, 1994), there is a strong point for taking potential restrictions in these abilities of older users into account.

Design guidelines based on abilities that are susceptible to age-related decline indeed generally focus on age-related functional limitations, not on user preferences. It seems reasonable to suppose that, apart from esthetical considerations, a user's preference is also based on a user's functional capacity. For example, a user with poor eyesight may be more proficient if a website has large letters and graphics and may for this reason have a tendency to prefer this type of website. Research on the relationship between performance and preferences is scarce. However, there is empirical evidence that people's design preferences do not always match designs that are predicted to be optimally usable based on their capabilities. For instance, a study by Bernard, Liao and Mills (2001) showed that for online reading purposes, a 14-point serif font supported faster reading, while older adults in the same study (62 – 83 years of age) actually preferred a sans serif font. Thus, despite the fact that a user's preferences probably resemble the user's abilities, it is important to consider such preferences when developing interface guidelines – a website that is designed to meet it's users' abilities but not their preferences may be less attractive to (and thereby less effective for) it's intended users.

The present study set out to investigate web design preferences in older and younger adults by strictly manipulating a series of design aspects within a context of a fixed interface design. We were primarily interested in people's first impression of the usability of a website, not in the actual usability of that website based on performance measures. Therefore, we asked older and younger Internet users to judge the usability of several websites on face value. Given that older users experience more difficulties when navigating websites than do younger users due to age-related limitations, it was expected that older users prefer websites that take such limitations into account. Younger adults have fewer physical and cognitive limitations than older adults, or may have different opinions on design esthetics, and may therefore have different preferences. Still, the approach of universal design (Story, Mueller, & Mace, 1998) assumes that the usability of products, including user interfaces, is optimal when these products have been designed for people of all ages and abilities. Thus, from this perspective, guidelines that are designed for older adults should also be appropriate for younger adults, which could imply similar preferences for the design of websites in different age groups.

Our second question concerned whether user preferences are consistent with existing guidelines. Table 1 provides an overview of a number of guidelines, derived from the literature, formulated for older interface users. These guidelines were mainly based on observed age-related changes in visual, perceptual, cognitive and motor skills. Unfortunately, there has been very little research into the relationship between these guidelines and actual performance of older computer users, and therefore, only general guidelines are available at the present time (Czaja & Lee, 2003). The guidelines cover aspects of interface design that were also included in the present study. We assumed that a user's preferences match his/her abilities and thus that older users' preferences are compatible with these guidelines.

Table 1 *Interface design guidelines for older adults used in this study*

	Guidelines
Text	Avoid using small character sizes [1,2,3,4,5]
	Use sans serif fonts [2, 3, 4]
	Use left justified text; avoid centered or full justification [2, 3]
Visibility	Maximize contrast between characters and background [1, 2, 3, 4, 5]
	Place text on unpatterned background [2, 3, 5]
Visual clutter	Apply principles of perceptual organization (e.g. grouping) [1, 4]
	Present information on consistent locations [1,2]
	Use white space actively [2,3]
	Use headings or subheadings [2]
	Avoid flashing/blinking text [2]
	Clearly label each section [3]
	Avoid using elements that compete for attention [4]
Navigation	Minimize number of hyperlinks in a line of text [2]
	Use buttons with symbols and text [2]
	Provide visual feedback on selection [2]
	Use icons as hyperlinks rather than underlined text [3]
	use placement conventions common to other sites [5]
Orientation	Avoid multi-column format or frames [2]
	Minimize demands on spatial and working memory [1, 2, 3]
	Avoid walking menus [3]
	Provide visual cues for environmental support [3]

Note 1) Czaja & Lee, 2003, 2) Echt, 2002, 3) Holt & Morrell, 2002, 4) Laux, 2001, 5) Mead et al., 2002

Methods

Participants

Participants in this study were recruited at the public library of the city of Maastricht, the Netherlands. Visitors of the library were randomly approached and asked to take part in the study. Participants were required to have some Internet experience. 107 Individuals, aged 19 to 78 years, agreed to participate. The participants were divided into four age groups: (1) 19-34, (2) 35-49, (3) 50-64 and (4) 65-80 (for an overview, see Table 2).

Table 2 *Demographic variables per age group*

	N	Age (M, SD)	Sex (m/f ratio in %)	Education (1-8)	Occupation (0-7)
1 (19-34)	34	26.2 (4.3)	44/56	5.8 (1.1)	4.4 (1.5)
2 (35-49)	30	42.3 (4.4)	47/53	5.8 (1.1)	5.0 (1.5)
3 (50-64)	29	57.1 (4.0)	59/41	5.5 (1.4)	4.8 (1.4)
4 (65-78)	14	68.9 (4.4)	86/14	5.5 (1.7)	5.3 (1.5)

Measurements.

User preferences were tested in two ways: using screen examples and by giving generic examples of web designs in questionnaire format. As preferences to more general features of web design, such as the use of roll over effects or frames, do not depend on the context, these preferences were measured with broader questions. Also, design aspects that could not be altered from the original website, such as different types of orientation cues, were presented to the participants in the questionnaire. On screen, examples of existing websites were shown to the participants. Only websites were selected which aimed for a general public. Of each website, different versions were subsequently presented, in which one distinct design characteristic (e.g. font size, background contrast) was changed. The screen examples, which are discussed in more detail below, are available at *http://www.pivo.unimaas.nl/docs/webdesign_PIVO_total_2509.ppt*. These versions were presented on a standard notebook computer (Apple Macintosh iBook, screen resolution: 24 bit, 800 x 600), using standard presentation software (Microsoft PowerPoint). As was mentioned above, these guidelines were mostly formulated based on observed age-related decline and have not been empirically tested. Therefore, we could not rely on existing material to compare the guidelines with user preferences. Instead, it was chosen to represent each of the categories of the guidelines in Table 1 and to use web screens that are likely to be encountered by any user to ensure ecological validity (e.g. portal websites, websites with large amounts of text, or websites with pictures). Participants were asked to choose the version of the website they considered most pleasant to work with.

In addition to the web design items, the questionnaire included items on demographic status and Internet usage. Demographic questions included date of birth, sex, level of education, and level of occupational activity. Level of education was measured with a Dutch scoring system (De Bie, 1987) consisting of an 8-point scale, ranging from primary education to university education. Participants' professions were given 4-digit codes (CBS, 1985) which were subsequently transformed to the 7-point level of occupational activity (LOA) score. This LOA score is based on a functional classification (Van den Brand *et al.*, 1990) and ranges from low skilled to academic labour. The questions about Internet use included the number of years participants had used the Internet and the frequency of use (hours per week). Participants could indicate for which purposes they used Internet.

Both the on-screen web design items and the questionnaire web design items focused on one of five dimensions of web design. The first dimension was "text". Two on-screen items were included to measure preferences with respect to font size and font type. For the first item, a portal-like website consisting of links to other websites on a similar topic was shown with several font sizes, ranging from 8 pt. to 16 pt. Font type (serif and sans serif) was varied on a website which contained a large amount of text. In the questionnaire, participants were asked which text justification they preferred (left, centred or right).

The second dimension was "visibility". A website containing general information on an academic course was used to present different text/background contrasts (positive - black letters on a white background- or negative -white letters on a black background-) and different letter contrasts (four versions ranging from light grey letters on a white background to black letters on a white background). Using the same website, four background-related web design features were manipulated. First, participants were asked if they preferred the presence of a photo or a logo in the background to a blank background, or vice versa. Next, preferences to different background contrasts characteristics were measured, namely contrast and blur level. The former feature was manipulated using a background photograph of a class of students, of which the opacity ranged from 20 to 80 percent in four steps. The latter feature was varied by applying four different blur levels to the same background photograph.

The third dimension of web design was labelled "visual clutter", referring to the amount of information on a website. One on-screen item showed a newspaper homepage, once with moving pictures (as present on the original website), once with non-moving pictures and once without pictures. Three related questionnaire items were included to ask participants about their preferences of using (non-)moving pictures in general and their preferences to information that is presented in a well-thought, usable way (with consideration of the abilities of the user).

The fourth dimension was labelled "navigation". An on-screen item showed a simple search engine website (Google) with several versions of a toolbar (text only, icons only, both text and icons). Four further questions in the questionnaire were included to ask participants which type of link they preferred (text, icon, or both), whether they preferred text-type hyperlinks placed within the main text of a website or placed in a separate column next to the main text, which location of separately placed hyperlinks they preferred (left, right, bottom, or top) and how pleasant they rated the use of roll-over effects (5-point Likert scale, ranging from very unpleasant to very pleasant).

The final web design dimension that was studied was called "orientation". For this dimension, three questionnaire items were used. First, participants were asked if they found the use of orientation cues to indicate one's location in the structure of the website pleasant or unpleasant (5-point scale). Next, they were asked to indicate which type of orientation cues they preferred (tabs, menus or links that change when one is on the corresponding page). Finally, participants were asked to rate the pleasantness of the use of frames or sub windows (5-point Likert scale ranging from very unpleasant to very pleasant).

Procedure

Participants were informed about the purpose of the study. After a brief instruction, they were seated in front of the laptop to view the versions of the websites. Each new website was introduced briefly on screen to direct participants' attention to the design characteristic of interest which was altered between the different versions of the website. After this, the different design versions of a typical website were subsequently presented with intervals of 3 seconds between the versions. Next, participants were allowed to leaf through the versions by themselves, at their own pace. All participants were instructed to judge the versions of the websites according to subjective usability, that is, they were specifically asked to indicate which of the versions they considered most pleasant to work with. After ticking off the preferred choice on a score form, the next web design characteristic was introduced. After all website versions had been presented and scored, participants were asked to fill out the questionnaire.

Statistical analyses

ANOVAs were conducted to determine whether the age groups differed with regard to level of education, years of Internet experience, and frequency of Internet use. Chi^2-tests were used to analyse differences between the age groups in terms of sex and types of Internet activities reported. Both ANOVAs and Chi^2-tests were conducted to analyse preferences regarding web design features (both on-screen and questionnaire items). If the ANOVA showed a significant effect, Tukey post-hoc tests were done to make pair-wise comparisons between all age groups.

Results

Group comparisons

The demographic characteristics of each age group are presented in Table 2. The groups did not differ in terms of level of education and occupation, but did in sex composition: unlike age groups 1, 2 and 3, age group 4 consisted mainly of men (12 men vs. 2 women).

Internet activities

Means for Internet experience, frequency of Internet use and number of Internet activities are shown in Table 3. The four groups did not differ with respect to experience, frequency, and the number of Internet activities. The Internet activities were further dichotomized ('used' or 'not used'), to analyze them separately, to study whether the choice of particular activities differed between the age groups. A significant effect was found for only one of the eleven activities: chatting ($\chi^2(3, N = 107) = 9{,}59$, $p = .02$). The number of participants who used the Internet for chatting decreased steadily with age: from 29.4% in group 1 to 0% in group 4.

Table 3 *Participant's use of Internet per age group*

	Experience (years)	Frequency (no. per week)	Activities (total no.)
1 (19-34)	6.7 (2.9)	7.3 (6.4)	4.3 (1.9)
2 (35-49)	5.9 (3.1)	10.8 (13.0)	4.5 (2.2)
3 (50-64)	5.2 (3.5)	7.3 (11.2)	3.2 (2.1)
4 (65-78)	5.8 (4.7)	4.5 (5.9)	3.8 (1.6)

Note In each column, means and standard deviations are presented

Web design preferences

Different aspects of web design were analyzed to investigate the effect of age on participants' preferences (see Table 4).

Table 4 *General information and statistical analyses of group differences for the on-screen and questionnaire items on web design*

Aspect of web design	Preference	F (3,124)	χ^2(df, N)	Sig.
Text				
Font size (8-16)	12.15 (2.18)	4.66		**
Font type (sans serif/serif)	52/48		(3,107) 8.19	*
Alignment (left, centred, right, no preference)	67/9/4/20		(9,107) 12.53	
Visibility				
Text/background contrast (positive/negative)	73/27		(3, 106) 3.11	
Letter contrast (high – low 1-4)	3.92 (.28)	1.83		
Background contrast (low – high 1-4)	1.44 (.69)	3.06		
Background sharpness (low – high 1-4)	2.92 (1.25)	4.55		*
Photo background (blank/photo)	61/39		(3,107) 16.66	**
Logo background (blank/logo)	78/22		(3,107) 6.49	**
Visual clutter				
Presence of pictures (unpleasant - pleasant 1-5)	3.32 (1.00)	4.76		**
Presence of pictures (pictures, no pictures, moving pictures)	41/39/20		(6,107) 19.50	**
Presence of moving pictures (unpleasant – pleasant 1-5)	2.19 (1.13)	1.32		
Well-designed presentation of information (unpleasant - pleasant 1-5)	4.51 (.84)	.69		
Navigation				
Type of toolbar (text/icons/both)	15/16/69		(6,107) 4.59	
Type of links (text/icon/no preference)	60/12/28		(6,107) 3.34	
Links in text? (in text/outside text/no preference)	43/32./25		(6,106) 1.62	
Location of link (left/right/bottom/top/no preference)	70/4/4/4/18		(12,106) 7.53	
Use of roll-over (unpleasant - pleasant 1-5)	3.69 (1.07)	2.49		
Orientation				
Use of orientation cues (unpleasant - pleasant 1-5)	4.18 (1.03)	.53		
Type of cues (tab/menu/changing link/ no preference)	19/57/11/13		(9,106) 6.12	
Use of frames/sub windows (unpleasant – pleasant 1-5)	3.30 (1.10)	.52		

Note For ordinal variables, ANOVAs were conducted. In the table, means and standard deviations as well as and F-values are given for each item. For nominal variables, χ^2 –tests were done. In the table, total percentages and the χ^2-values (with degrees of freedom) are given for each option.
Sig. = significant result, *p<.05, **p<.01

On-screen items. There were significant differences between the age groups for the two font-related aspects, font size and font type. The participants in groups 3 and 4 preferred larger fonts (mean preferred font sizes were 12.8 pt. and 13.4 pt. respectively) than the participants in group 1 (p = .04 and p = .01, mean preferred font size was 11.4 pt.) (see Figure 1). The differences in font type were less straightforward (Figure 2). Most participants in groups 1 and 3 preferred a sans serif font type, while most participants in group 2 and 4 preferred a serif font type.

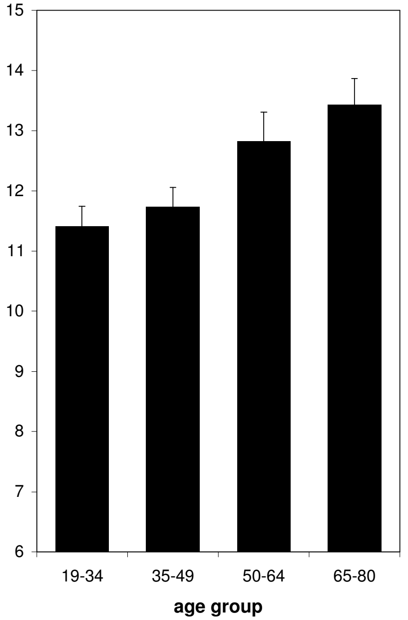

Figure 1 *Mean (SE) preferences to font size*

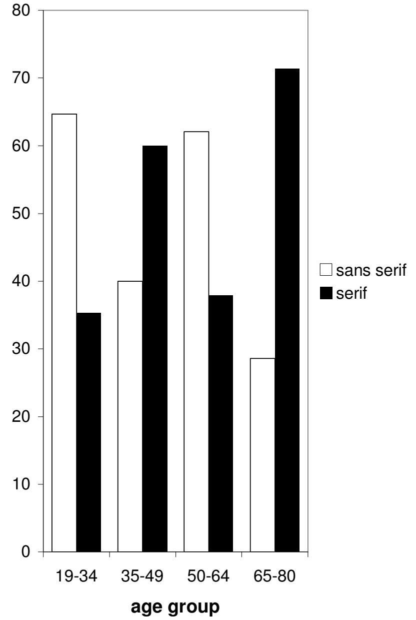

Figure 2 *Preferences to font types in percentages of participants*

The age groups also differed significantly in their preference for pictures, no pictures, or moving pictures on a website (see Figure 3). Participants in groups 1 and 2 preferred the website version with non-moving pictures, whereas participants in groups 3 and 4 preferred versions with no pictures. They also differed in their preference for a blank or a photo background to a website. About half of the participants in groups 1 and 2 preferred a photo background (58.8% and 50.0% respectively), whereas about 80% of the participants in groups 3 and 4 (86.2% and 78.6%, respectively) preferred a blank background (see Figure 4). If a photo background was used, there were differences in the preferences for contrast and blur of the background (see Figure 5 and 6). Post-hoc analyses revealed that the participants in group 3 preferred a photo with lower contrast compared with participants in group 1 (p = .02). Also, participants in group 3 preferred a higher blur level of the photo background, that is, a less sharp photo, than the participants in group 1(p < .01).

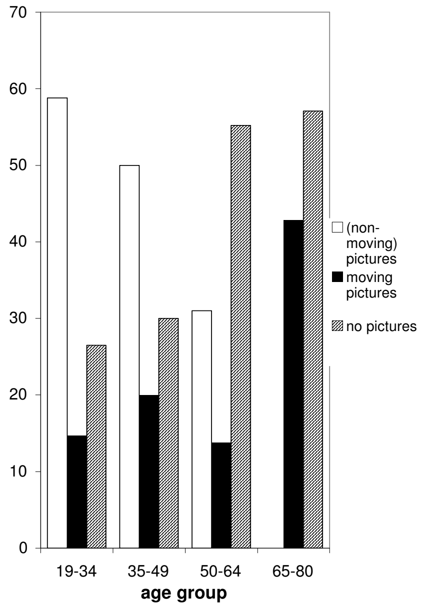

Figure 3 *Preferences to (non-moving) pictures, moving pictures or no pictures in percentages of participants*

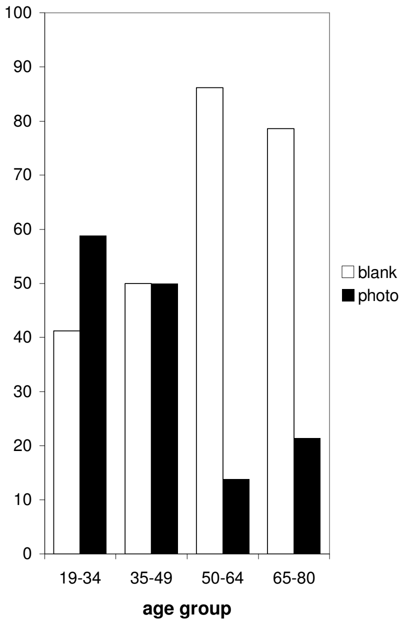

Figure 4 *Preferences to a blank background versus a photo background in percentages of participants*

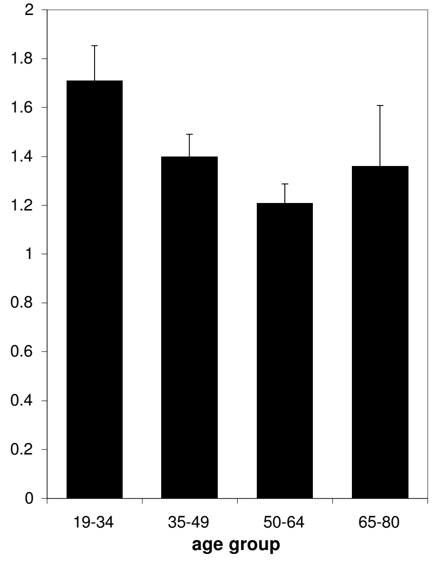

Figure 5 *Mean (SE) preferences to the contrast of a photo background*

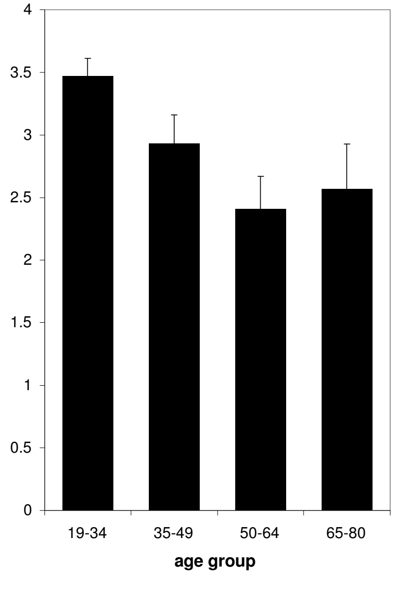

Figure 6 *Mean (SE) preferences to the sharpness (blur level) of a photo background*

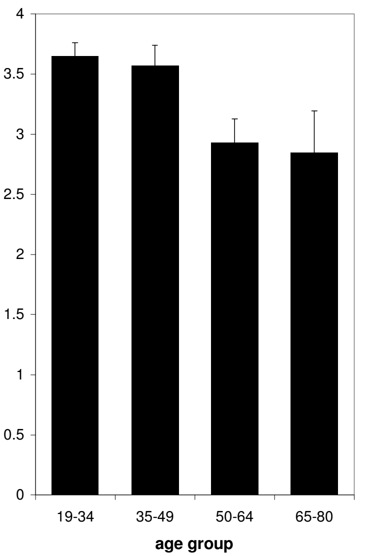

Figure 7 *Mean (SE) preferences to the use of (non-moving) pictures*

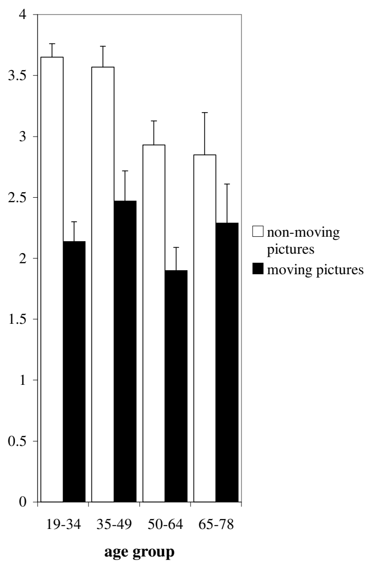

Figure 8 *Mean (SE) preferences to both the use of moving and non-moving pictures in percentages of participants*

Questionnaire items. The questionnaire indicated a significant difference between age groups with respect to the presence of (non-moving) pictures (see Table 4). Post-hoc analysis showed that the participants in age groups 3 ($p = .02$) and 4 ($p = .05$) found the presence of pictures less pleasant than did the participants in age group 1 (see Figure 7), which is in line with the results of the on-screen "presence of pictures" item. No differences between age groups were found for the presence of moving pictures. However, t-tests, which compared these two items, showed that the participants in groups 1, 2, and 3 found moving pictures less pleasant than non-moving pictures ($t(33) = 9.10$, $p < .01$ for group 1, $t(29) = 6.28$, $p < .01$ for group 2, $t(28) = 5.13$, $p < .01$ for group 3 and $t(13) = 2{,}10$, $p = {,}06$ for group 4) (see Figure 8).

Discussion

The aim of this study was to compare the preferences for web design features of older and younger web users and to identify any discrepancies between these preferences and existing guidelines for interface design. Overall, the preferences of older and younger users corresponded quite well – an effect of age was found on three aspects of web design, namely, font (both type and size), the use of a photo as background (a photo background compared with a blank background and with regard to the contrast and level of blur of the photo), and the presence of (non-moving) pictures. As has been argued above, one of these differences may be mediated by age-related functional decline. Older participants preferred larger font sizes, possibly due to reduced eyesight. The differences between the age groups with respect to font type are more difficult to interpret because the age effects were less meaningful. The results regarding font size and font type partly correspond to the results reported by Bernard et al. (2001), which were described above. We found a preference for the similar font type (14 pt.) as recommended by Bernard et al. On the other hand, participants in their study preferred a sans serif font type, where 60 percent of our oldest participants preferred a serif font type. The difference in preferences between younger and older computer users with respect to font size was not very large (2 points), but apparently, older adults tend to be more satisfied with websites with a font size of 14 points than a font size of 12 points.

Next, older adults preferred a blank background (instead of a photo background) whereas the younger participants (groups 1 and 2) had a less pronounced preference on this point. Older adults may find it harder to extract relevant information from the screen and may find irrelevant information on a website, including a patterned background, more distracting. The same holds for the presence of (non-moving) pictures, which younger users preferred more than older users did. With respect to the contrast and level of blur of a photo used as background, the middle-aged participants (group 3; 50 to 64 years of age) preferred a lower contrast and higher level of blur. This can be related to differences in contrast sensitivity, i.e. foreground/background discrimination, which steadily declines with age (van Boxtel, ten Tusscher, Metsemakers, Willems, & Jolles, 2001). Surprisingly, the age differences for both items were found only for the participants of group 3 but not for the participants of group 4. A possible explanation for this may be a cohort effect, as participants in the oldest age group were probably the only participants in this study who had not been introduced to computers in a school or work situation. Instead, most of these people started to use the Internet completely out of their own interest and motivation. These participants probably were high functioning older adults and might not be fully representative of average older adults.

Overall, there appeared to be few differences in web design preferences between older and younger users. This favors the universal design approach, which assumes that design principles aimed at accommodation of the older user should also be beneficial to younger users. We found no evidence to suggest that younger users might not appreciate interfaces that meet these principles.

We compared our user preferences with current interface guidelines (see Table 1). Most of these guidelines were consistent with the participants' preferences, but some differences were found. We did not find a clear preference for sans serif font types, which are recommended in several guidelines (Czaja & Lee, 2003; Echt, 2002; Holt & Morrell, 2002; Laux, 2001; Mead et al., 2002). Also, Echt (2002) recommended minimizing the number of hyperlinks within text, whereas most of our participants preferred links to be embedded in the text rather than outside the text. We also have not found a preference for the use of icons as hyperlinks and the use of walking menus, as was recommended by Echt (2002) and Holt & Morrell (2002). Most of our participants preferred text to icons as hyperlinks and the use of walking menus as an orientation cue to the use of tabs or changing links. These differences between guidelines and user preferences suggest that people's preferences are not entirely based on their functional capabilities, and that other factors, such as aesthetics, may also play a role. When designing a web interface therefore, we suggest to not only take users' capabilities into account, but also to ask potential users about their preferences. When these preferences contradict the performance measures, it should be considered to prioritize the preferences, as these may render a website more attractive to the users. When solely focusing on users' capabilities, one may make sure that the user can easily navigate the website. However, usability does not only concern the effectivity and efficiency of use, it is also defined by the user's satisfaction (ISO, 1998). Hence, to perceive a website as a useful one, ideally the user should be satisfied about all aspects of the website.

Based on the results of the present study, it is not possible to conclusively decide what exactly influences users' preferences to the design of web interfaces. The preferences may not only be affected by cognitive abilities, but may also be determined by factors such as aesthetics. To be able to decisively establish the effect of age-related cognitive decline on older users' web performance, more research in larger groups of individuals is necessary. As measures of physical limitations and performance were not taken in this study we cannot draw definite conclusions about the actual relation between user preferences and capabilities. Still, this study is the first to show that user preferences need to be taken into account next to capacity-based considerations.

Another issue that is associated to the relationship between the existing guidelines and the user preferences found in the present study concerns the study material. As was discussed earlier, the existing guidelines were not based on empirical findings by manipulating actual interfaces to test user performance. These guidelines are based on commonly observed age-related declines in vision, perception, cognition and motor skills. This implies that the guidelines may be used for very different types of websites, where we have only manipulated the design aspects in one typical, but specific web design. Therefore, it may be possible that the type of website and the task (e.g. reading, searching for information) affect the preferences of the user with respect to the guidelines. Therefore, the present results can only be interpreted within the context of the material that was used. For the websites that were used in the present study, we are able to conclude that user preferences do not entirely match to the general design guidelines, which demonstrates the importance of taking user preferences into account as well.

The four age groups were similar in terms of both quantitative (experience in years and frequency of use) and qualitative (the types of Internet activities) aspects of Internet use. A possible limitation of our study is that the oldest group (group 4) was substantially smaller and had a different male/female composition than the other three age groups. These differences, however, do reflect the actual difference in age distribution of Internet users. For example, a recent survey of information technology use in the Dutch population (de Haan, 2003) revealed that fewer people in the oldest group (65 years and older) than in younger groups are connected to Internet (17% versus 50%–73%), which in part explains the difficulty with the recruitment of participants in the oldest category. As for the different male/female ratio in the oldest age group, we only found one significant difference between male and female participants, namely in the total study population female participants preferred hyperlinks located outside the mail text of a website and male participants preferred hyperlinks to be located in the text. That is, in general there were no significant differences between preferences for web design of male and female Internet users. Therefore, we do not expect such differences in the oldest age group as well.

In summary, we found few age-related differences in user preferences for web design features. Although most preferences matched ability-based guidelines, some differences were apparent, suggesting that users sometimes prefer versions of websites that may not optimally meet their perceptual, motor, or cognitive abilities. Therefore, when developing new guidelines and new websites or interfaces, designers should try to incorporate both user preferences as well as user functional abilities.

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Chapter 12

Concluding remarks

The primary aim of the research presented in this thesis was to study the effects of computer training and the subsequent use of a personal computer and the Internet on the autonomy of older adults. The focus of the longitudinal intervention study that was designed for this purpose was on five separate domains: cognitive ability, wellbeing and quality of life, the use of everyday technology, computer anxiety, and the development of upper limb complaints (RSI). It was found that the intervention produced no effect in any of these domains. That is to say, older adults who mastered computer skills and engaged in using a personal computer and Internet facilities for twelve months, and thus acquired a new complex cognitive skill, showed neither improvement nor deterioration with respect to several domains of autonomous functioning.

Besides this intervention study, three separate studies were carried out to investigate issues related to computer and technology use by older adults that were not part of the intervention study. These studies were done to explore the relationship between cognitive functions and everyday technological abilities; to study both age-related differences in predictors of computer use and the relationship between computer use and cognitive functions in younger and older adults in the Maastricht Aging Study (MAAS); and, finally, to investigate age-related differences in user preferences for several attributes of the design of web interfaces. These studies demonstrated that cognitive functions, particularly speed of information processing and cognitive flexibility, were important with respect to the ability to use technology that is essential to everyday autonomous functioning. Also, predictors of computer use were found to differ between younger and older adults. Whereas in younger adults only level of education predicted computer use, in older adults age, sex and loneliness were also significant predictors. In the same study it was observed that long-term computer use was related to changes in cognitive abilities. Using a computer prevented both younger and older adults from declines in selective attention and memory processes in a six-year period. However, this longitudinal association was small. Finally, web design preferences of older and younger users appeared to be very similar and some discrepancies between preferences and existing guidelines for designing web interfaces for older users were found.

In this chapter, the results described in the present thesis are discussed on a more general level. More specifically, the implications of the findings are considered with respect to the rationale of this thesis (presented in Chapter 2), to the application of interventions aimed at promoting autonomy in later life and for future research in this area, to design consequences from an ergonomic perspective and to recommendations for computer use by older adults.

Implications for the rationale: 'Use it or lose it' reconsidered?

Several studies so far have suggested that engagement in intellectually or cognitively challenging activities is associated with the preservation of cognitive capacity, suggesting that it may be possible to boost cognitive functioning by promoting the participation in such activities. These findings are in line with the theoretical notion of reserve capacity

(Mortimer, 1997; Staff, Murray, Deary, & Whalley, 2004; Stern, 2002), which assumes that higher levels of cognitive functioning enable individuals to sustain more (age-related) cognitive damage before symptom onset. This is also consistent with the 'Use-it-or-lose-it' notion that was put forward by Swaab in 1991. Translated to a functional level, this notion assumes that mental stimulation may have a protective effect against decline in higher brain functions in later life. Evidence for the latter has come from different sources (Bosma *et al.*, 2002; Hultsch, Herzog, Small, & Dixon, 1999; Stevens, Kaplan, Ponds, & Jolles, 2001). The findings of the intervention study presented in this thesis, however, were not in accordance with the expectations based on these notions. We found no evidence suggesting that healthy older adults who engage in a new cognitively challenging activity, learning to use computers and the Internet in this case, profit from this in any way by showing relative improvements in cognitive functioning compared with older adults who did not engage in this new activity during the same period. This also implies that encouraging older adults to use computers and the Internet is not a useful intervention strategy to promote successful (cognitive) aging within a one-year episode.

The fact that we found no effect of our intervention on cognitive abilities seriously disputes the validity of the notions of (cognitive) reserve capacity and Use-it-or-lose-it with respect to the prevention or reversibility of age-related functional decline in a relatively healthy, community-dwelling population of older adults. The studies that are usually put forward to support these notions only provide observational and retrospective data. The present study however, used a randomized, controlled design, which is a much more valid approach for testing these hypotheses. Therefore, the findings of the present research seriously challenge the idea that it is possible to protect healthy older adults from age-related cognitive decline by stimulating them to engage in cognitively challenging activities. However, some issues remain that may be addressed in future research. These questions are discussed in the following section.

Another theoretical approach that has been studied in the research described in this thesis was the concept of transfer in problem solving ability, assuming that previous experience may be used to devise a solution for a new problem or task (Mayer & Wittrock, 1996). According to this idea, individuals who have acquired computer skills may use these skills to solve problems in other technological domains as well. Regarding this question, we again did not find supporting evidence. Therefore, we conclude that no transfer of technological problem solving skills is to be expected as a result of mastering new computer skills by older adults. As was the case with the lack of supporting findings for the concepts of cognitive reserve and Use-it-or-lose-it, some questions remain for possible future research that are discussed below.

Implications for the application of interventions: Suggestions for future research

The main conclusion of this thesis is that no evidence was found to suggest that it is effective to stimulate healthy older adults to use computer and Internet facilities to boost their cognitive reserve. Therefore, we consider computer-based interventions on a large scale developed for this purpose to be not very effective. However, there may be some issues in this context that are worthwhile considering in future research. First, as was pointed out in Chapter 4, the intervention period of twelve months may have been too short. On the other hand, other cognitive intervention studies, although not exactly similar to the present study with respect to size and target group (e.g. Ball *et al.*, 2002; Kliegl, Smith, & Baltes, 1989; Schaie & Willis, 1986; Stigsdotter & Backman, 1995), with even shorter follow-up durations, provide support for the idea that one year should be long enough to detect differential improvement as a result of an intervention like the one used in the present study. This idea that longer periods of computer use yield similar effects to those of our one-year period was supported by the results reported in Chapter 10 where, retrospectively, no substantial effects of computer use on changes in cognitive abilities over a longer period (six years) were found in the Maastricht Aging Study.

A second issue that might be considered in future research is the question of whether older adults with specific background characteristics might benefit from interventions using a broad approach to improve mental stimulation from which healthy older adults did not benefit. For instance, it is possible that individuals with functional limitations, such as Mild Cognitive Impairment (MCI) (Petersen *et al.*, 1997) or low levels of acquired brain damage, may improve as a result of learning to use computers and the Internet. This was actually suggested by results of similar, but smaller, intervention studies using computers and the Internet (Cody, Dunn, Hoppin, & Wendt, 1999; McConatha, McConatha, & Dermigny, 1994; McConatha, McConatha, Deaner, & Dermigny, 1995). The participants in these studies were not community dwelling healthy older adults, but residents of nursing homes or other care facilities. It may be hypothesized that when older adults have more to gain in terms of both cognitive abilities and aspects of wellbeing and quality of life, computers and Internet-based interventions are more effective. An issue one has to bear in mind, though, is that teaching complex skills, such as operating a personal computer and surfing the Internet, may be quite hard to accomplish in individuals with cognitive limitations. In any case, such studies should be pursued using a randomized controlled design, particularly to control for bias in the training phase, as was done in our study.

A final suggestion for future research may be that older adults who have already mastered computer skills may not show observable benefits from this experience until they have to cope with more substantial age-related cognitive challenges at later stages in their lives. For instance, the ability to use computers and the Internet may provide them with more supportive strategies to deal with these limitations. Since none of the participants showed such limitations in the present study sample, this possibility should be investigated more thoroughly. However, studying this option implies much longer intervention periods. This in turn may be hard to accomplish with an adequately controlled design because of the decreasing population of older adults without computer experience, the ethical issue of refraining participants from computer use for such a long period, and the risk of selective attrition.

In addition to the implications of the findings presented in this thesis for the rationale of improving cognitive reserve, some other practical consequences and suggestions for further studies should be noted. First of all, we found no evidence suggesting that teaching general technological computer skills to older adults generalized to their use of everyday technological devices. Therefore, we suggest that future research should focus on identifying and developing other strategies to improve older adults' execution of everyday tasks. Potential approaches in this context may be training methods aimed at specific actions or devices, design solutions, a focus on generational differences in technological abilities, or a dedicated type of psycho-education to remove psychological barriers older adults might have in the use of technological applications. Another suggestion concerns the exploration of possible conditions under which transfer of technological skills in older adults does occur. As was mentioned in Chapter 7, one possible cause of the lack of this transfer may be the fact that the older adults in this study were not able to recognize the similarities between computers use and the use of other everyday technologies. Finding ways to help individuals recognize analogies between familiar and novel tasks may be an effective strategy for improving technological abilities.

A second practical implication is related to the finding that teaching individuals computer skills and stimulating them to use a personal computer and several Internet facilities for personal use is not an effective method to decrease computer anxiety in novice older computer users. However, this should also be thoroughly investigated in the general population of older adults because the majority of our participants were willing to participate in a computer-based intervention and may therefore have had lower levels of computer anxiety from the start. Nonetheless, based on the present results, we recommend that future studies should aim at developing other types of programs to reduce computer anxiety in older adults more effectively. As was the case with developing programs to reduce problems with everyday technological tasks, psycho education to help older adults recognize their barriers with respect to computer use may reduce their level of computer anxiety. To be able to develop suitable programs aimed at reducing computer anxiety in older adults, the findings presented in Chapter 8 are important, which imply that one should account for the fact that predictors of computer anxiety in older adults may not be identical to those in younger people. In particular, it was found that older introvert adults and individuals who are not particularly interested in using computers are at risk of developing computer anxiety. Since these predictors were studied in a population of older adults without computer experience, future research should identify such predictors in other older populations as well.

A final recommendation based on the present intervention study is that when stimulating older adults to use computers, e.g. because of the practical benefits computers and the Internet have to offer, older adults who are not inclined to start using computers on their own should be the target population for future interventions. As was reported in Chapter 10, among older adults women, individuals who are older, individuals who have lower levels of education and individuals who feel lonely could be specifically targeted. One positive note, as was found in Chapter 9, is that there is no reason to assume that special precautions should be taken to prevent older novice computer users from developing upper limb complaints due to computer-based leisure-time activities.

Ergonomic implications: Technological design considerations for older adults

Design solutions were suggested as being important with respect to three separate issues in this thesis. First, in Chapter 8, it was suggested that employing suitable design solutions that take older adults' capacities into account might reduce computer anxiety. For instance, since it was suggested in the literature that experience with computers is a prerequisite for developing computer anxiety (e.g. Beckers & Schmidt, 2001), ideally an individual's first experience with computer applications should be positive. Therefore, designers of computer software should account for age-related capabilities, such as reduced speed of information processing and higher levels of distractibility, in order to facilitate intuitive use of such programs. As a result, older adults' early computer experiences may be positive, as a result of which the chance of developing high levels of computer anxiety is reduced.

The second topic where good design may be important is the use of everyday technological applications that are important to autonomous functioning, such as automatic teller machines, ticket vending machines and mobile telephones. It has very often been reported that older adults experience more problems in using such devices than younger adults do (Charness, Bosman, Kelley, & Mottram, 1996; Czaja & Sharit, 1993; Rogers, Gilbert, & Fraser Cabrera, 1997) and therefore design solutions might be used to improve older adults' execution of everyday technological tasks. In Chapter 6 it was demonstrated that cognitive abilities known to decline with age, in particular speed of information processing and cognitive flexibility, are important to performing everyday technological tasks. Therefore, designers should be aware of the changing cognitive capacities of older adults when developing new technological applications. It was also found that the exact cognitive abilities playing a role in everyday technological task execution are task dependent. For this reason, one should identify these specific abilities in the design process of each new device.

The final area in which ergonomic recommendations are important to supporting older adults is in the design of web interfaces. In Chapter 11 it was concluded that preferences of computer users do not always match the design guidelines that are generally formulated on the basis of the users' capabilities. In other words, sometimes users prefer design features of websites that are not in accordance with general user-specific guidelines. Therefore, it is recommended that designers not only apply these capability-based guidelines, but also involve the intended users in the design process in order to be able to take their preferences into account. In addition, only few differences were found between preferences of younger and older computer users with respect to design features of websites. Moreover, no evidence was found suggesting that younger adults do not appreciate interfaces that were designed to meet older users' capabilities, which is in accordance with the idea of universal design (Story, Mueller, & Mace, 1998). Therefore, older users' capabilities and preferences are considered to be of most importance in designing web interfaces.

In conclusion, ergonomic design solutions have the potential to play an important role in the autonomy of older adults. As was mentioned recurrently in this thesis, to remain autonomous older adults need to be able to deal with a variety of technological or even computer-based applications. To stimulate and simplify the use of such applications, older adults' capabilities, attitudes and preferences should be accounted for in the design.

Implications for the target group: Recommendations for older adults

Although no effects of using computer and Internet facilities were found, we feel that older adults should still be stimulated to (start to) use computers. Even though no quantifiable positive effects of computer use are to be expected on cognitive abilities and several measures of wellbeing and quality of life, the practical benefits that computer and Internet facilities have to offer make using these facilities very worthwhile for older adults. Examples of these benefits that can be of particular interest in regard to older adults are services that facilitate life-long learning (such as online courses), entertainment (games, chatting etc.), and practicing one's hobbies (for instance by access to more information and the ability to come into contact with people with the same interest). Therefore, we still recommend that older individuals should be motivated to engage in computer-based activities, not in order to objectively improve their autonomous functioning and wellbeing, but in order to allow them to profit from the numerous practical and entertaining features of both computers and the Internet.

Conclusion

The findings presented in this thesis provide knowledge about possible strategies to promote successful (cognitive) aging. In conclusion, it was found that teaching older adults computer skills and stimulating them to use the Internet for twelve months - an attempt to improve both the level of cognitive functioning and the level of active engagement with life - is not an effective method to help older adults age more successfully. This finding is not in accordance with the often-stated assumption that older adults should benefit from using computers and the Internet with respect to domains such as autonomy, social network and psychological wellbeing. This contrast shows the importance of evidence-based research methods to test commonly accepted beliefs. By conducting a randomized controlled trial in this case, it was possible to examine an idea that has great societal potential, but which could cost a lot of time and money to carry out on a large scale. As was shown by the present studies, it is very worthwhile experimentally testing such assumptions before actually implementing them. Therefore, comparable trials in gerontological research should be pursued. In sum, by conducting thorough and systematic research, we were able to test and reject the generally believed assumption of a beneficial effect of using computers and the Internet on several aspects of autonomy of healthy older adults. Therefore, the present research has provided an important contribution to existing knowledge of promoting successful cognitive aging.

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Summary

The research described in this thesis aimed at studying the impact of acquiring computer skills and of using a personal computer and Internet facilities on several aspects of autonomy in later life. This was done by carrying out a large scaled (N = 236) randomized controlled intervention study with multiple control groups. In addition to the intervention study, of which the outcome is presented in Chapters 4 to 9, two separate studies were done. The first study focused on predictors of computer use and the relationship between computer use and cognitive functioning in the general population (using data from the Maastricht Aging Study). The second study investigated age differences in computer users' preferences regarding web interface design.

The rationale of these studies originated from the concepts of reserve capacity, cognitive reserve and the 'use it or lose it' notion, which are addressed in Chapter 2. In accordance with these concepts it was argued that stimulating the use of cognitive abilities may have the potential to boost cognitive reserve in older persons. Moreover, it was hypothesized that teaching older adults to use a personal computer and the Internet is an efficient strategy to target multiple cognitive abilities simultaneously. In addition, the acquisition of information technology skills was suggested to support the autonomy of individuals in later life. So far, firm evidence for these notions was lacking.

The main research questions of the present research concerned the effect of the computer and Internet intervention on the cognitive abilities, autonomy, everyday functioning, wellbeing and the social network of older adults. In Chapter 4, data are described that showed no effect of this intervention on multiple domains of cognitive function; no differences in changes in cognitive parameters over time were found between the intervention group and the control groups. Similar results were found with respect to autonomy, wellbeing and social network, which are presented in Chapter 5. That is, the present intervention did not have any effect on cognitive abilities and several measures of autonomous living and wellbeing in later life.

To study the relationship between newly acquired information technology skills and the ability to solve everyday technological tasks, a new and ecologically valid test, the Technological Transfer Test (TTT), was developed. In Chapter 6, the role of cognitive abilities in performing technological tasks is explored. It was found that speed of information processing and cognitive flexibility predicted performance on most of the separate technological tasks. This implies that age-related cognitive decline may have a profound effect on the interaction between older adults and technological appliances. The TTT was subsequently used to test whether a transfer of information technology skills to solving new technological tasks occurred or not. The results, described in Chapter 7, showed that exposure of older adults to a novel technological challenge did not affect the efficiency of and involvement in other technological activities. Thus, there was no transfer of general technological skills to everyday technological task performance.

Two aspects that might interfere with a healthy use of computers by older adults are addressed in Chapters 8 and 9. The study presented in Chapter 8 aimed at both identifying predisposing factors of computer anxiety and the impact of computer training and Internet use on changes in computer anxiety. It was found that older individuals without active computer experience, who were interested in computers and the Internet, and who were more extrovert had lower levels of computer anxiety. Still, computer anxiety did not change as a result of computer use. It is concluded that prevention programs aimed at reducing or preventing computer anxiety should account for age-specific predictors of computer anxiety. In addition, exposure to computer use is not an effective strategy for reducing computer anxiety. Because older adults may have a higher risk of developing RSI, Chapter 9 addresses the question whether the twelve-month use of a standard computer for leisure purposes would promote complaints of upper limb pain or functional limitations in novice older computer users. Both before and after the intervention, no differences between groups were found with respect to upper limb complaints and to general health, physical and mental health and pain. Furthermore, no differential change in the scores was found as a result of the intervention. This first randomized, prospective study on this topic implies that prolonged, self-paced use of a standard computer interface does not promote upper limb complaints or reduce functional health in older adults.

In sum, the results of the intervention study showed that older adults who acquired a new skill which draws heavily on different domains of their cognitive capacity, neither improved nor deteriorated with respect to cognitive ability, autonomy, wellbeing and quality of life, the use of everyday technology, and the development of upper limb complaints (RSI). Therefore it is concluded that that teaching older adults computer skills and stimulating them to use the Internet for twelve months is not an effective method to help normal older adults to age more successfully.

A separate study that was carried out in addition to the intervention study focussed on the predictors of computer use and the relationship between computer use and changes in cognitive abilities over a six year period in the general population and was described in Chapter 10. Data were obtained from the Maastricht Aging Study, a longitudinal study into determinants of cognitive aging. The results showed age-related differences in predictors of computer use: level of education was the only predictor in younger participants, while in older participants, sex and feelings of loneliness were also informative for the extent of computer use. Furthermore, it was found that computer use protected both older and younger individuals from deteriorations in measures of selective attention and memory. However, effect sizes were small, which indicates that using computers did not have a practically relevant effect on cognitive change.

Because of the impact of age-related cognitive decline on the ability to interact with modern technology, as was found in Chapter 6, many guidelines for designing websites for older users exist. Next to age-related differences in cognitive capabilities, preferences of young and older persons with respect to web interface design may differ. The final research chapter, Chapter 11 focuses on a study that compared the preferences of older and younger users on several characteristics of web design. These preferences were also compared with existing guidelines. Web design preferences of older and younger users appeared to be very similar and largely corresponded to those incorporated into general guidelines. However, some discrepancies between guidelines and preferences were found, and therefore, user preferences should be taken into account in web interface design in addition to user capabilities.

In the final chapter, findings presented in this thesis are discussed on a more general level. Implications are addressed for the rationale, for the application of interventions aimed at improving cognitive abilities of healthy older adults, for the target group, and for designing technological applications for older adults.

Samenvatting

In het onderzoek dat beschreven wordt in dit proefschrift stond de impact van het aanleren van computervaardigheden en van het gebruik van computer- en internetfaciliteiten op verschillende aspecten van de autonomie van ouderen centraal. Dit werd onderzocht door middel van een grote (N = 236) gerandomiseerde, gecontroleerde interventiestudie met meerdere controlegroepen. Naast deze interventiestudie, waarvan de resultaten worden gepresenteerd in Hoofdstuk 4 tot en met 9, werden twee aparte studies uitgevoerd. De eerste studie was gericht op voorspellers van computergebruik en de relatie tussen computergebruik en cognitief functioneren in de algemene populatie (data uit de Maastricht Aging Study werden gebruikt). In de tweede studie werden leeftijdsverschillen in voorkeuren van computergebruikers ten opzichte van ontwerpaspecten van websites onderzocht.

De rationale van deze studies komt voort uit de concepten reserve capaciteit, cognitieve reserve en het 'use it or lose it' idee, die worden besproken in Hoofdstuk 2. Op basis van deze concepten werd beargumenteerd dat de cognitieve reserve van oudere individuen verhoogd zou kunnen worden door hen te stimuleren hun cognitieve vaardigheden actief te gebruiken. Bovendien werd voorspeld dat het leren gebruiken van een computer en het internet door ouderen een efficiënte strategie is om meerdere cognitieve vaardigheden tegelijkertijd te activeren. Tenslotte werd gesuggereerd dat het verwerven van informatietechnologische vaardigheden de autonomie van ouderen kan ondersteunen. Gefundeerd bewijs voor deze ideeën ontbrak tot nu toe echter.

De belangrijkste onderzoeksvragen voor dit onderzoek hadden betrekking op het effect van een computer- en internetinterventie op de cognitieve vaardigheden, de autonomie, het dagelijks functioneren, het welbevinden en het sociale netwerk van ouderen. In Hoofdstuk 4 worden gegevens besproken die geen effect lieten zien van de interventie op verschillende domeinen van cognitief functioneren; er werden geen verschillen gevonden in veranderingen in cognitieve parameters tussen de interventiegroep en de controlegroepen. Vergelijkbare resultaten werden gevonden met betrekking tot autonomie, welbevinden en sociaal netwerk, die worden gepresenteerd in Hoofdstuk 5. Kortom, de interventie had geen effect op cognitieve vaardigheden en verschillende maten van zelfstandig functioneren en welbevinden bij ouderen.

Om de relatie te bestuderen tussen aangeleerde informatietechnologische vaardigheden en het vermogen om dagelijkse technologische taken op te lossen werd een nieuwe en ecologisch valide test ontworpen: de Technologische Transfer Test (TTT). In de studie die wordt beschreven in hoofdstuk 6 werd de rol van cognitieve vaardigheden bij het uitvoeren van technologische taken onderzocht. Snelheid van informatieverwerking en cognitieve flexibiliteit bleken de prestatie op de meeste van de technologische taken te voorspellen. Dit betekent dat leeftijdgerelateerde cognitieve achteruitgang een belangrijk effect heeft op de manier waarop ouderen omgaan met technologische applicaties. Vervolgens werd de TTT gebruikt om te testen of er een transfer van informatietechnologische vaardigheden naar het oplossen van nieuwe technologische taken optreedt of niet. De resultaten, beschreven in Hoofdstuk 7, lieten zien dat een nieuwe technologische uitdaging voor ouderen geen invloed heeft op de omgang met dagelijkse technologieën. Er vond dus geen transfer plaats van algemene technologische vaardigheden naar dagelijkse technologische prestatie.

Twee aspecten die mogelijkerwijs interfereren met gezond computergebruik door ouderen worden besproken in Hoofdstuk 8 en 9. De studie die wordt gepresenteerd in Hoofdstuk 8 ging in op factoren die van invloed zijn op computerangst en de impact van computertraining en internetgebruik op computerangst. De resultaten toonden aan dat ouderen die geen actieve computerervaring hebben, die geïnteresseerd zijn in computers en internet, en die extraverter zijn, minder computerangst vertonen. Echter, computerangst verminderde niet als gevolg van computergebruik. Er word geconcludeerd dat programma's die zijn gericht op het voorkomen of verminderen van computerangst rekening zouden moeten houden met leeftijdsspecifieke voorspellers van computerangst. Ook bleek dat het stimuleren van computergebruik geen effectieve strategie is om computerangst te verminderen. Omdat ouderen mogelijk een hoger risico lopen op het ontwikkelen van RSI, wordt in Hoofstuk 9 ingegaan op de vraag of computergebruik het risico verhoogt op klachten in arm, pols en schouder of op functionele beperkingen voor startende oudere computergebruikers. Zowel voor als na de interventie werden geen verschillen tussen groepen gevonden in klachten aan arm, pols en schouder, en in algemene, fysieke en mentale gezondheid en pijn. Verder werden geen verschillen gevonden in deze scores als gevolg van de interventie. Deze studie geeft aan dat langdurig computergebruik klachten aan arm, pols en schouder niet verhoogt en de functionele gezondheid van ouderen niet verlaagt.

Samengevat laten de resultaten van de interventiestudie zien dat ouderen die een nieuwe vaardigheid aanleren die verschillende domeinen van hun cognitieve capaciteiten aanspreekt, noch verbeteren, noch verslechteren met betrekking tot hun cognitieve vaardigheden, autonomie, welbevinden en kwaliteit van leven, het gebruik van dagelijkse technologie en het ontwikkelen van klachten aan arm, pols en schouder (RSI). Daarom word geconcludeerd dat het aanleren van computervaardigheden en het stimuleren van internetgebruik voor een periode van twaalf maanden geen effectieve methode is om succesvol ouder te worden.

Een aparte studie die werd uitgevoerd in het kader van dit proefschrift was gericht op voorspellers van computergebruik en de relatie tussen computergebruik en veranderingen in cognitieve vaardigheden in een periode van zes jaar. Data voor dit onderzoek werden verkregen uit de Maastricht Aging Study, een longitudinale studie naar de determinanten van cognitieve veroudering, en worden beschreven in Hoofdstuk 10. Uit de resultaten bleek dat er leeftijdgerelateerde verschillen zijn in voorspellers van computergebruik: opleidingsniveau was de enige voorspeller in jongere deelnemers, terwijl in de groep oudere deelnemers computerangst ook nog werd voorspeld door geslacht en eenzaamheid. Verder werd gevonden dat computergebruik zowel oudere als jongere individuen beschermt tegen verslechtering van selectieve aandacht en geheugen. Deze effecten waren echter zo klein dat er geen sprake is van een praktisch relevant beschermend effect van computergebruik op cognitieve veranderingen.

Vanwege de impact van leeftijdgerelateerde cognitieve achteruitgang op de vaardigheid om met moderne technologie te kunnen omgaan, zoals werd gevonden in Hoofdstuk 6, bestaan er vele richtlijnen voor het ontwerpen van websites voor oudere gebruikers. Naast leeftijdgerelateerde verschillen in cognitieve vaardigheden, zouden er ook verschillen kunnen bestaan in voorkeuren van jongere en oudere gebruikers ten opzichte van het ontwerp van websites. In het laatste onderzoekshoofdstuk, Hoofdstuk 11, wordt een studie beschreven waarin deze voorkeuren van jongere en oudere gebruikers ten opzichte van verschillende ontwerpkenmerken werden vergeleken. De voorkeuren werden tevens vergeleken met bestaande richtlijnen. Voorkeuren voor webontwerp van oudere en jongere gebruikers bleken weinig van elkaar te verschillen en kwamen ook grotendeels overeen met de richtlijnen. Er werden echter ook enkele verschillen gevonden tussen voorkeuren en de richtlijnen en ontwerpers van websites zouden naast de capaciteiten van gebruikers rekening moeten houden met hun voorkeuren.

In het laatste hoofdstuk worden alle bevindingen van dit proefschrift op een generieker niveau besproken. Implicaties worden aangegeven voor de rationale, voor het toepassen van interventies die zijn gericht op het verbeteren van cognitieve vaardigheden van gezonde ouderen, voor de doelgroep en voor het ontwerpen van technologische toepassingen voor ouderen.

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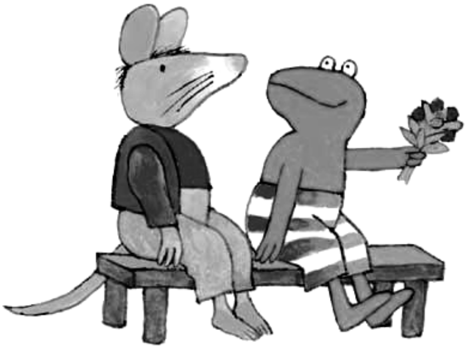

Curriculum Vitae

Karin Slegers werd geboren op 11 maart 1978 te Noordoostpolder. In 1996 behaalde zij haar VWO diploma aan het Corderius College in Amersfoort. Hierna begon ze met haar studie Psychologie aan de Universiteit Maastricht. In 2001 studeerde zij af in de Cognitieve Psychologie, specialisatie Cognitieve Ergonomie, met een onderzoeksstage bij TNO Human Factors in Soesterberg. Van 2001 tot en met 2005 werkte zij als Assistent in Opleiding bij de vakgroep Neurocognitie van de Faculteit der Psychologie aan de Universiteit Maastricht. Het onderzoek dat zij hier deed is beschreven in dit proefschrift. Sinds januari 2006 is zij werkzaam op de Research & Development afdeling van Vodafone in Maastricht.