Effects of computer training and internet usage on cognitive abilities in older adults: a randomized controlled study

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ABSTRACT. ***Background and aims:*** *According to the concepts of 'use it or lose it' and cognitive reserve, cognitively challenging activities may boost cognitive abilities in older adults. Using computers and the internet provides divergent cognitive challenges to older persons, and the positive effects of computers and internet use on the quality of life have been found in earlier studies.* ***Methods:*** *We investigated whether prolonged guided computer use by healthy older adults (64-75) may be beneficial to cognitive ability in a randomized controlled study. The intervention consisted of brief training and subsequent use of a personal computer with an internet connection at home for a 12-month period. 191 participants were randomly assigned to three groups: Intervention, Training/No intervention, or No training/No intervention. A fourth group consisted of 45 participants with no interest in computer use. The effect of the intervention was assessed by 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.* ***Results:*** *Intensive interaction with a personal computer with standard software applications had no effect on cognitive measures; no differences in changes in cognitive parameters over time were found between groups.* ***Conclusion:*** *Learning to use a computer and the internet does not benefit healthy, community-dwelling older adults with respect to many domains of cognitive functions. The implications of these findings for future studies that use cognitive challenge to counteract usual cognitive aging are discussed.*
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INTRODUCTION

Most cognitive abilities tend to decline with age (1). For instance, Schaie (2) found almost linear negative differences between several age groups, ranging from young adulthood to old age, in inductive reasoning, spatial orientation, perceptual speed and verbal memory, but not in numeric and verbal abilities. An important question, however, is whether this decline in many cognitive abilities 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 et al. (3) 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. (4), 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 (defined as activities requiring '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 (5). 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., 6, 7). 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 cognitive functioning can be improved by promoting the participation of older persons in cognitively challenging activities. This idea is in line with Swaab's 'use it or lose it' principle (8), 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

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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 can counteract the reduced efficiency of higher brain functions that come with age. This has actually been found in several animal studies in which enriched or challenging environments proved to be beneficial to cognitive functioning in aged laboratory animals (e.g., 9, 10). 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 (11).

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., 12, 13) or mnemonic techniques (14, 15), 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 (15, 16) have been taught successfully and shown to improve in older adults.

The studies cited above suggest that cognitive functions in older adults can be improved 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 shopping involves planning (how to get to the grocery store), memory (which items to buy), information processing (e.g., recognition: "identifying products in the store", selective attention: "which of the items in the store shelve are relevant", decision-making: "which of the items to choose to buy"), 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 (12).

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., 17, 18). 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. Therefore, through the internet, one may use the same cognitive functions that are required to execute everyday tasks (such as memory for remembering errands, attention to focus on a particular task, etc.). In terms of "use it or lose it", by using cognitive functions during computer and internet use, deterioration of cognitive functions that are essential to everyday tasks due to age-related decline may be prevented. 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. Furthermore, Stronge et al. (19) mention the importance of problem-solving ability and concept formation, which is essential for building a mental framework of computer-related knowledge representations. Spatial orientation is also considered an important ability for web surfing, in order to keep track of one's location in cyberspace (20).

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 show 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., 17, 18). A limited number of studies have actually focused on the impact of computer and internet use on cognitive functioning as the primary outcome. McConatha et al. (21) showed that, in a small sample (n=14) of long-term care residents aged between 59 and 89, the score on 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 encyclopedia, bulletin boards, games, and other educational and recreational applications. Comparable results were found in a subsequent study, in which 29 nursing home residents aged 50 and older were divided into a computer training group and a control group (matched in terms of ability to take care of daily needs, cognitive functioning and depression level) (22). Participants in the training group used the same on-line computer service as had been used in the previous study, and those 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 had improved in MMSE, ADL and depression scores, whereas 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 may affect the results of internet-based intervention studies such as described above. For instance, as participation in such an intervention is on a 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 participants' interest in learning to use these facilities in order to be able to study exclusively 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 above-mentioned cognitive abilities needed to use the internet decline with advancing age (for an extensive overview, see ref. 1) and as information technologies are often unfamiliar to older adults, it is to 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 can be counteracted by aspecific mobilization of cognitive resources.

We conducted a randomized controlled intervention study to test the above-mentioned hypothesis. A large group of participants with interest in computer usage was recruited from the general population and randomly assigned to three conditions in which a cognitive challenge (an intervention consisting of computer and internet use for twelve months) was present or not present. 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 whether complex cognitive activity that is practised on a regular basis in daily life can be beneficial to the cognitive function of older persons.

METHODS

Participants

For the present study, we aimed at recruiting 240 participants in four separate groups. Invitation flyers were randomly sent to older adults from the Maastricht city register. Participants 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 center. Exclusion criteria were prior experience with any of the neuropsychological tests used in this study and general mental functioning in a range suggesting possible cognitive disorder (score below 24 on the MMSE) (23). Also, participants were to have no prior active computer experience and be willing to refrain from computer use or computer lessons for the duration of this study (i.e., twelve months). Both participants with and without interest in learning to use computers and the internet were asked to respond to the flyer by returning an application card for more detailed information. On this card they could indicate by ticking one of two options whether they were interested in learning to use the internet or not (but were willing to participate). All participants signed a form stating that they would refrain from any self-initiated computer use during the study, and signed an informed consent form. The Medical Ethics Committee of Maastricht University Hospital approved the study.

It was decided that exposure to the intervention was to be compared with three control groups. Two groups consisted of individuals with interest in learning to use the internet, as was the case with individuals in the intervention group. One of these two groups received the same training as those in the intervention group. The other group was not trained in computer or internet skills. These two control groups made it possible to control for training effects. The third control group consisted of individuals without any interest in computers or internet use, but who were willing to participate in the study. Participants who were interested were randomly assigned to the Intervention, Training/No Intervention or No Training/No Intervention Groups.

Procedure

A total of 6054 individuals received the flyer, and 1016 (16.8%) persons applied for more detailed information. After reading it, 366 (36.0%) individuals who were interested in participation called the research center for a screening interview by telephone. Two hundred and forty individuals (65.6%) were eligible for the study and were scheduled for two baseline administrations of a cognitive test battery. This dual baseline administration (with one to two weeks in between) was applied to minimize procedural learning of the tests during the intervention period. Cognitive data from the first baseline measurement were discarded. One hundred and twenty-six people (34.4%) were excluded from the study because of: computer experience, n=54; health-related problems, n=14; experience with tests from the test battery, n=11; they were not willing to refrain from computer use during the study, n=4; no cable TV connection at home (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', put off by the test procedure, or a score of below 24 on the MMSE. The test battery was administered again after four and twelve months, with parallel test versions. A questionnaire was also administered on all three test occasions.

Initial recruitment did not yield sufficient participants for the control group, so again an invitation was sent to 585 new people from the municipal registry to recruit only additional participants who were not interested in computers and the internet. After these two recruitment procedures, the number of participants in the control group after baseline was kept at 45.

Participants who were interested in learning to use computers and the internet (n=191) were randomly assigned to one of two conditions: two-thirds of the participants (n=123, 64.4%) received brief training; and one-third (n=68, 35.6%) did not receive this training and were assigned to the No training/No intervention Group.

Participants in the training condition were scheduled for three four-hour training sessions over a period of two weeks. In these sessions, a maximum of six participants were introduced to and could practice with, a personal computer (Apple) and its operating system, customary software applications (e.g., a word processor), and several internet applications (e.g., an internet browser and e-mail). The training sessions were supervised by two teachers with high levels of proficiency in internet applications, the system software, and providing technical support. Each teacher hosted one specific session for each training group (either focusing on the computer operating system and software skills or on internet applications). The teachers alternately supervised the final practice session. Participants received general information and were instructed on how to perform basic computer and internet assignments from a custom-made course book. Ample time was available at each meeting to practise with several applications according to participants' own aspirations. After this training, participants were randomly assigned to one of two conditions: half (n=62) were assigned to the Intervention Group and the other half (n=61) to the Training/No intervention Group. No data were collected with respect to training activities.

After training, individuals in the Intervention Group received a personal computer with a broadband internet connection in their homes. They were instructed to use it according to their personal needs. These needs were not specified or assessed. In training, participants received demonstrations of several purposes for which the internet could be used (e.g., e-mail contact with family and friends, finding hobby-related information, finding opening hours, public transport time schedules, phone numbers, etc.). Internet-related assignments (once every two weeks in the first four months; once every month in the remaining period of the study) and a helpdesk were used to motivate participants and to stimulate computer use. Table 1 shows the 16 assignments participants received by e-mail. They were asked to respond to them by replying to the e-mail. These assignments were thus useful in monitoring the progress of participants with respect to their computer abilities. When no response was received, participants were contacted, to encourage them to keep checking their mailbox and to complete each assignment. At the same time, participants were given suggestions of potentially interesting purposes of the internet.

In short, the procedure was identical for participants in the various groups from several viewpoints: all participants were administered the same test battery and questionnaires at baseline, and after both 4 and 12 months. Also, participants in all three No-Intervention Groups had to re-

Table 1 - *Internet-related assignments for participants in Intervention Group.*

	Assignment
1.	Reply to an e-mail
2.	Go to seniorweb (URL provided) and click on "computer & internet". Find this week's question in the poll.
3.	Go to the website of the local supermarket (URL provided) and find the special offers of this week. Send an e-mail to the researchers with some of the offers and the prices.
4.	Go to the website of the local Tourist Information (URL provided) and find the number of Italian restaurants that are listed.
5.	Go to the website of a local paper and cut and paste one of the main newspaper reports into a Word file. Attach this file to an e-mail.
6.	Go to a website about France (URL provided) and cut and paste a photo into a Word file. Attach this file to an e-mail.
7.	Go to the website of the Rijksmuseum to find the present exhibitions. Cut and paste this information into an e-mail.
8.	Go to the website of our project (URL provided) and click on "participants" and then on "forum". Leave a message on this forum.
9.	Go to the website of the local theatre and find the shows that are on stage this weekend.
10.	Go to the website of the Netherlands Railways and find the time of arrival of the first train to Amsterdam that departs after 9:00 am.
11.	Go to the website about public transport (URL provided) and find the travel advice for the route from your house to our research center (address provided). Cut and paste this advice into an e-mail.
12.	Go to the route planner on the website of the Dutch Automobile Club and find out how long it takes to drive from your house to Luxembourg City. Cut and paste the travel advice into an e-mail.
13.	Go to an e-card website (URL provided) and send an e-card to the researchers.
14.	Go to the website of the city library and find a book (title and author provided) in the catalog. Cut and paste the information you found into an e-mail.
15.	Find a photo or drawing of the coat-of-arms of the Netherlands. Cut and paste this picture into a Word file and attach it to an e-mail.
16.	Find an advertisement on a Dutch website for a second-hand printer that is Macintosh-compatible. Cut and paste this advertisement into an e-mail.

frain from using computers during the twelve months of the study.

Nineteen participants (8.1%) dropped out before the 4-month follow-up, and six participants (2.5%) were not available for the 4-month follow-up measurements (one participant was absent for a long time; one did not like the tests and questionnaires, one was disappointed by the randomization result; one was too worried about personal memory performance; one could not be reached; and one gave no reason). Another thirteen participants (6.0%) dropped out before the 12-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 for 204 participants. A few participants did not complete all questionnaires, which resulted in Cognitive Failure Questionnaire (CFQ) data of 231 participants at baseline and complete follow-up data for 196 participants. *Post hoc* power analyses on the available number of participants with complete follow-up data, with a medium critical effect size of 0.15 and an alpha level of 0.05, resulted in a power of 0.99 for this study (24). The participant flow chart of the study is shown in Figure 1.

Outcome measures

To study several dimensions of cognitive functions, we chose to include a broad array of well-established cognitive tests that were derived from several large-scale longitudinal studies (25, 26).

Verbal memory. The Visual Verbal Learning Test (VVLT) (27) was used to measure verbal memory and learning. In this test, 15 monosyllabic low-associative words are presented one after another on a computer screen. After the presentation, participants are 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, participants are again asked to recall as many words as possible (delayed recall).

The score in the first trial of the immediate recall, sum of the scores in the first three trials and delayed recall scores were used in this study. In addition, the difference between the maximum scores in any of the five trials and the scores 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) (28) was added. This test is administered with a six-button panel,

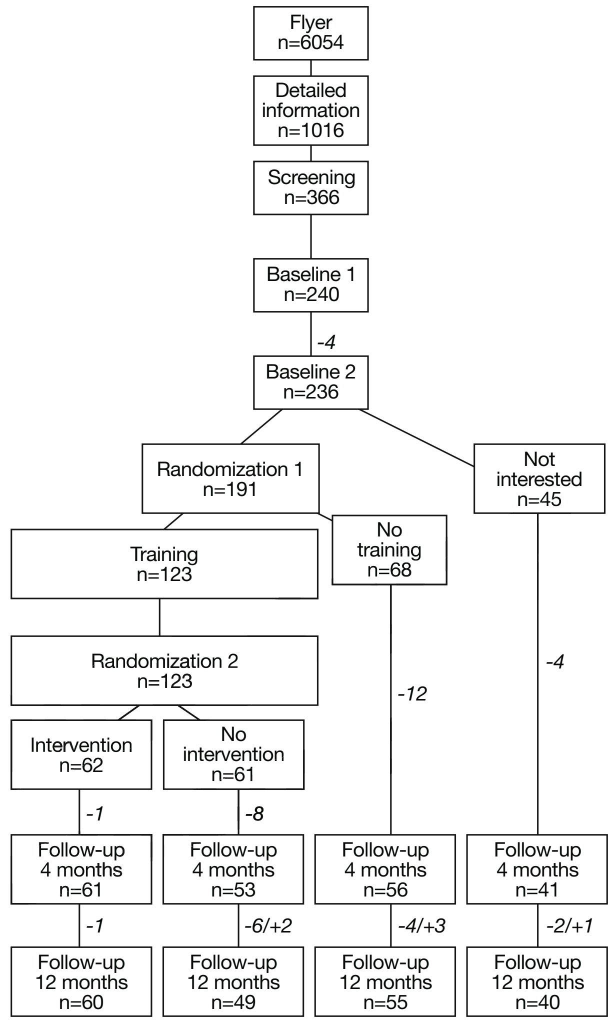

Fig. 1 - *Flowchart of recruitment.*

containing one red button and five white buttons, laid out in a semicircle around the red button. 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 lit up, 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 (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, but 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. First, the difference between the median response times of the second and first conditions was used as an indication of response selection. Secondly, a measure of inhibition of a prepotent response (29) was provided by the difference between the third and second conditions.

General cognitive speed. The Letter-Digit Substitution Test (LDST) (30) was used to measure the speed of processing general information. This test is a modification of the Symbol-Digits Modalities Test (31). 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 as possible in boxes that contained only letters in 90 seconds.

Cognitive flexibility. The Concept Shifting Test (CST) (32) was used to measure cognitive flexibility. This test consists of three sheets of paper with 16 small circles that are grouped within a larger circle. On the first sheet, numbers appear in the small circles in a fixed random order. Participants are 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, except that now 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 Color Word Test (SCWT) (33) was used as a measure of selective attention and susceptibility to interference. The test contains three cards. On the first card, color names are printed in four lines of ten words each. Participants are asked to read the names aloud as fast as possible. On the second card, colored patches are printed in the same layout as the words on the first card. Here, participants are asked to name the color of each of the patches as fast as possible. On the third card, color names are printed in incongruously colored ink. Participants have to name the color 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 (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) (34) was included to measure subjective cognitive functioning. It has been validated and adapted for the use in a Dutch population (35). 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 4-month and 12-month follow-up moments, participants were asked to indicate how many hours per week they had used the computer and the internet. These questions were asked retrospectively at the end of the follow-up tests. That is, participants were not asked to keep a continuous record of their computer use because this might have intruded with their experience of normal computer use. We chose to rely on self-report data instead of logging participants' computer use for two reasons. First, without asking participants for log-in names or passwords, it was not possible to separate their computer use from the use of potential other users, such as spouses or visiting grandchildren. Second, when logging computer use, we would have had to inform participants of this, which may have affected the way the computer was used during the study.

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 socio-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, Control Group) and time as a within-subject variable (three levels: second baseline, 4-month follow-up, and 12-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. The 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 a median split method on the number of hours per week participants said they used their computers at the 12-month follow-up. In this case, the median was 7.5 hours, so that participants who reported using their computers 7 hours per week or less were labeled 'light users' and those who reported using them 8 hours per week or more were 'heavy users'. All variables included in the analyses were first checked for normal distributions, missing values and outliers. Distributions were considered suitable

Table 2 - *Means (SD) for all cognitive variables at each measurement moment for four groups, main effects of group, and group x time interactions.*

	Training/ Intervention	**Training/ No intervention**	**No training/ No intervention**	**Control Group**	**Overall group effect *p*-value**	**Group x 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	11.82 (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)		
QFC	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)		

*Statistically significant at p=0.05.

for the analyses. All analyses were carried out 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 $p=0.05$ as significance level.

RESULTS

Baseline comparisons

At baseline, the four groups did not differ with respect to age, sex, level of education, monthly income or MMSE score. When participants who were interested in the intervention were compared with participants who were not interested, differences were found with respect to the MMSE scores ($F(1,231)=4.321$, $p=0.04$) and the CFQ ($F(1,226)=4.118$, $p=0.04$): interested participants had lower MMSE scores but reported fewer cognitive failures. These differences were not found in 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 in level of education ($F(1,229)=4.129$, $p=0.04$) and the MMSE score ($F(1,234)=4.097$, $p=0.04$) Participants who dropped out had lower levels of education and a lower MMSE score.

Computer use

At the 4-month follow-up measurement, on average participants reported using their computers 8.7 hours per week (SD=5.8). At the 12-month follow-up, this average was 8.3 (SD=6.2) hours per week. The difference between 4 and 12 months 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 4-month follow-up, and 6.5 (SD=5.6) hours per week at the 12-month follow-up. Again, the difference between the two moments of measurement was not statistically significant.

Effects of intervention

Table 2 gives an overview of the main effects of group on the three measurements and of the interaction between group and time. The 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. Pairwise comparisons revealed that participants in the Intervention Group showed higher total scores in the VVLT ($p<0.01$) over time than those in the Training/No intervention Group. Also, participants in the Intervention Group showed better flexibility scores in the CST compared with the Training/No intervention Group ($p<0.01$). Lastly, participants in the Training/No intervention Group were faster in terms of the simple speed measure of the SCWT compared with the Intervention ($p<0.01$), the No training/No intervention ($p<0.01$) and Control Groups ($p=0.01$). A group x time interaction was only found for the verbal learning variable of the VVLT ($F(6,178)=2.196$, $p=0.04$). *Post-hoc* analyses showed that both Training Groups showed an increase in the verbal learning variable from baseline to 4-month follow-up measurements, whereas neither No training Groups showed a decrease (see Fig. 2). The difference between the Intervention and the No training/No intervention Groups was significant ($p=0.04$). No statistically significant main effects of group or significant group x time interactions were found on any of the other cognitive measures, nor on the CFQ.

Repeating all analyses with exclusion or replacement of extreme values did yield comparable results. Also, all analyses were repeated with only baseline measurements and 12-month follow-up measurements, as six participants were not available for the 4-month follow-up (and therefore not included in the original analyses). These analyses again yielded comparable results.

As regards the extent to which participants in the Intervention Group used their computers, a significant difference between light and heavy use at baseline was only found for the interference variable of the SCWT ($F(1,50)=4.607$, $p=0.04$). Participants who used their computers 8 hours or more per week had lower 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 ($F(1,41)=10.125$, $p<0.01$), summed score on the first three trials of the VVLT ($F(1,41)=7.578$, $p<0.01$), verbal learning capacity score of the VVLT ($F(1,41)=5.425$, $p=0.03$) and interference score on the SCWT ($F(1,40)=6.617$, $p=0.01$). 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 needed less time to inhibit a habitual response in the SCWT. Instead, 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 scores of the first three trials of the VVLT ($F(2,46)=3.533$, $p=0.03$), showing that, in the first four months of the intervention, the summed score of heavy computer users decreased, whereas that of light users increased ($p=0.02$). The same was found for the delayed recall score in the VVLT ($F(2,46)=4.885$, $p=0.01$). Here, the difference in change between light and heavy users was significant, both between the 4-month follow-up and baseline measurements ($p=0.02$) and also for the period between the 12-month

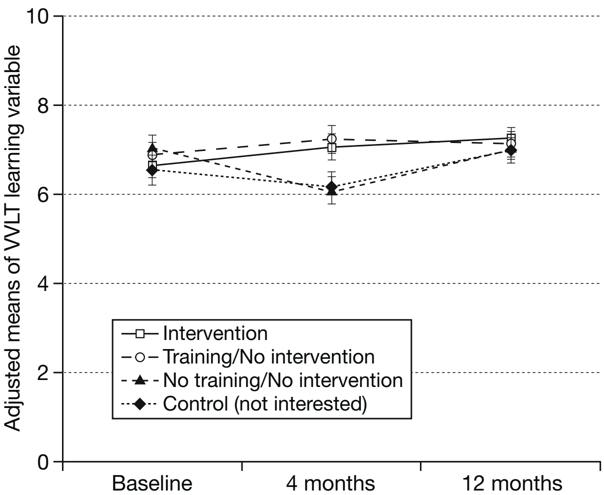

Fig. 2 - *Means of four groups at each measurement moment of VVLT learning variable, adjusted for age, sex, education and income.*

follow-up and baseline measurements (p=0.01). Lastly, an interaction effect was found in the LDST (F(2,46)=4.300, p=0.02). Between the 4-month follow-up and baseline measurements, heavy computer users showed an increase in the number of correctly substituted digits, whereas light computer users showed a slight decrease (p=0.01). Thereafter, between the 4-month and 12-month follow-ups, heavy computer users again showed a decrease and light computer users a slight increase (p=0.03).

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 our measures of cognitive abilities. No effect of intervention was found on almost all these measures. A difference in change over time between the groups was actually found on only one cognitive measure, i.e., the learning variable of the VVLT. However, this interaction effect between group and time was quite random and did 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 could not 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 8 hours or more per week had better scores in trial one of the VVLT, summed score of the VVLT, and 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. Instead, participants who used their computers less than 8 hours per week showed better verbal learning scores. This was 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 heavy computer users. These results suggest that there is a relationship between computer use and cognitive abilities in older adults. However, as the differences between light and heavy computer users did 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 in older adults, which showed that these functions improve as a result of training or intervention (12, 15, 16, 36). One major difference between these studies and our study which 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 (37). 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 those who were not interested in the intervention with respect to uncontrolled characteristics that may also have had 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 the social attention to which the participants of intervention studies are exposed. Since social interactions during training sessions may have had an effect that is not related to the actual intervention, we included a control group that received the same training as the Intervention Group.

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 did yield positive effects on several psychosocial (17, 18, 21, 22, 38, 39) and cognitive measures (21, 22).

There are a number of differences between our study and the limited number of studies that found effects of an intervention on cognitive ability measures. The first major difference is the study population. Both of the abovementioned studies included residents of care facilities, i.e., 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. Since similar interventions do yield improvements of the cognitive abilities of care facility residents, it is possible that individuals who have functional limitations may improve as a result of learning to use computers and the internet. Older adults with such limitations, that is, individuals with a reduction in reserves and an increasing number of losses amongst others within the cognitive domain, may have more potential to improve with respect to these losses. For instance, older adults with memory deficits may improve more as a result of training memory functions than older adults with normal or high memory functioning. This is a research topic that could be explored in future studies, including participants with fewer optimal cognitive abilities in intervention studies. However, it should be borne 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 earlier studies using computer-based interventions concerns the measures of cognitive ability. Both of the above-mentioned studies (21, 22) 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 this, 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, but we 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 to this study. One explanation for the lack of an effect of our intervention on cognitive ability is that the intervention did not challenge the cognitive capacity of our participants sufficiently. 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 difficulty 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., 40). Thus, learning to use computers and the internet requires considerable cognitive effort from older adults. Another reason why it is not very plausible 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 8 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 study period. Overall, we do not believe that the intervention was insufficient in providing a true cognitive challenge for participants.

Also, based on the present study, we are able to conclude that using computer and the internet has no effect on the measures of cognitive functioning used in this study. However, we cannot rule out that such an intervention has no effect on other aspects of human cognitive functioning. That is, using computers may be beneficial for functions such as spatial abilities, visual search, etc. However, within the scope of the present study, most of the cognitive functions essential to everyday autonomous performance were represented in the test battery, for none of which we did find an effect of the intervention.

Lastly, despite a very strict study design, we were not able to account for some aspects that might have influenced results. For instance, we cannot rule out the possibility 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, although it does seem to be long enough to detect differential improvement, as supported by other cognitive intervention studies with similar or shorter follow-up durations (e.g., 12, 15, 16, 36). Another related issue which we are not able to resolve here, but which may be very relevant for the independent functioning of older adults, is that older individuals who have learned to use a computer and the internet have better strategies to cope with (cognitive) limitations they may encounter in later life. As personal computers and the internet have several promising functions in this respect (e.g., providing reminders for people with memory problems, easy contact with health care providers, ordering groceries for people with mobility restrictions, providing day schedules, including reminders, for people with declined executive functions, etc.), 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 is sometimes not very feasible because of problems such as high expenses and attrition.

CONCLUSIONS

We did not find any influence of learning to use computers and the internet on a broad range of cognitive ability measures in a healthy group of independently living older adults with no prior computer experience. 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 whether persons with more evident 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. Lastly, another question that remains interesting for future research is whether older adults who have received timely training in using computers and internet services remain independent longer when functional limitations start to emerge.

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