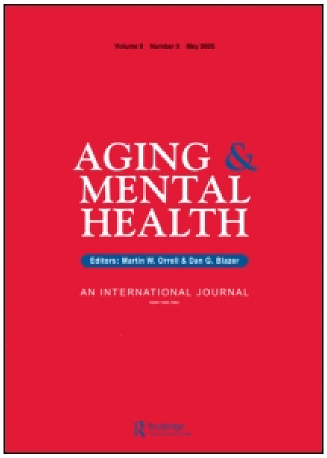

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Long-term improvements in cognitive performance through computer-assisted cognitive training: a pilot study in a residential home for older people

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ORIGINAL ARTICLE

Long-term improvements in cognitive performance through computer-assisted cognitive training: a pilot study in a residential home for older people

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Abstract

The aim of the present pilot study was to investigate the effects of computer-assisted cognitive training on aging-associated memory deficits, information processing speed, learning, and interference tendency in older people. Residents of a home for older people (15 women, four men; mean age 83.5; range 75–91) participated in a 14-week computer-assisted cognitive training program. The Nürnberg Aging Inventory and the California Verbal Learning Test were administered prior to the program, immediately after the program and after a period of five months to assess the effectiveness of the cognitive training. After the cognitive training program there were significant improvements in primary working memory and also secondary working memory (for verbal and visual stimuli), on parameters of information processing speed, learning and interference tendency. Improvements in the last two cognitive parameters were maintained five months after completion of the training program. The present study indicates that computerized cognitive training programs can be used in older people to achieve long-term improvements in some important aspects of fluid intelligence. It is suggested that computers could be employed more extensively to prevent and treat cognitive deficits in older people.

Introduction

About 50% of people aged 60 years and older report a marked decline in cognitive performance, particularly in remembering names, associating faces with names and in everyday short-term memory (Roberts, 1983; Leirer *et al.*, 1990). The subjective reports concur with a large amount of literature describing a number of facets of cognition, which demonstrate a marked age-related decline. These include primary working memory (passive retention and repetition within short time periods of up to 30 s), secondary memory (conscious retention of information, parallel processing and reorganization of the contents of memory), and information processing speed, inductive thinking, concentration, and the ability to classify. The common link between all these cognitive functions is that they are components of fluid intelligence and for this reason may be particularly vulnerable to changes brought about not only by drug therapy or medical intervention but also by pathological changes (Baltes *et al.*, 1995; Christensen *et al.*, 1994; Hambric *et al.*, 1999; Oswald, 1988; Salthouse, 1996; Verhaegen & Salthouse, 1997).

In the past 15 years many types of cognitive training programs for enhancing memory and concentration have been developed (Günther *et al.*, 1997). Many studies have shown that their efficiency, however, decreases as an inverse function of cognitive performance such that in patients with severe dementia, for example, memory aids are helpful only to some people (McPherson *et al.*, 2001). In contrast, persons with age-dependent cognitive deficits, or such deficits as may be clinically designated as 'mild', appear to profit from these intervention strategies, at least in the short-term, which may be due to a better retained reserve capacity (Baltes *et al.*, 1992). Studies evaluating long-term effects of cognitive training, however, show disappointingly heterogeneous results (Hasselhorn *et al.*, 1995; Martin & Kaiser, 1998).

Although computerized cognitive training is widely used in the rehabilitation of younger neurological patients and psychiatric patients (Giaquinto & Fiori, 1992), there has been very little research about its potential use in gerontology (Olbrich, 1998; Ott-Chervet *et al.*, 1998). The computer, however, may possibly have several advantages in cognitive training

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in older people (Bodenburg & Technow, 1992; Günther *et al.*, 1997; Hofmann *et al.*, 1996).

Most important amongst these potential advantages is arguably the promotion of motivation to learn, as unlike more traditional cognitive training methods the computer is able to directly measure success, and provide immediate, totally value-free feedback. Computer-assisted cognitive training also has the advantage of being flexible and comprehensive enough to allow systematic training of specific aspects of cognition that may be problematic. To date very few empirical studies have looked at the effects of computer-assisted cognitive training in older people. The study by Ott-Chervet *et al.*, (1998) included 28 patients from a geriatric hospital. Fourteen were assigned to computer-assisted cognitive training (nine hours within three weeks, with no follow-up). Results show that participants of the training generally improved their performance in all tasks of the program including attention and concentration, vigilance, and memory in the sense that tasks of a higher level were more easily solved. Superiority of the trainees over the control group in psychomotor skill was established by measurements using the trail making test. The authors point out that psychomotor skill is one of the fundamental parameters of human behaviour, tending to decline with age. The main limitation of this study is the lack of follow-up data.

In view of the paucity of data regarding computerized cognitive training in older people, the present study attempts to investigate the long- and short-term effects of a computer-assisted cognitive training program in a group of elderly persons with age-associated cognitive deficits. The primary aim of the study was to determine whether short- or long-term improvements in primary and secondary memory, information processing speed, and learning and interference tendency could be achieved by a computer-assisted training program. It was also hoped that the study would yield further information regarding the acceptance and use of computers by older people.

Methods

The study was conducted in a modern Tyrolean residential home with largely self-contained accommodation.

Subjects

Potential subjects were screened for suitability for the study and only those who were able to understand and complete a 45-minute computerized training session and a psychometric test battery were included in the study. The subjects comprised 25 elderly men and women aged between 75 and 91 years with age-associated memory impairment, having no signs of dementia (AAMI, Crook *et al.*, 1986; Hanninen *et al.*, 1996; Zaudig, 1995). Subjective and objective parameters for the assessment of cognitive deficits were employed. Subjectively, participants should, for instance, complain about memory problems in their daily lives such as having difficulties in remembering names or telephone numbers, constantly misplacing things, difficulties in quick recall of information or being quickly distracted. Memory disturbances must be capable of being objectively established in at least one of our entry tests, with the values showing a standard deviation below the test norm.

All participants consented to undergo computer-assisted cognitive training and psychometric testing before (t_1) and after the training program (t_2) and five months after the cognitive training (t_3). Participants suffered from the usual age-associated illnesses: one third of them had internal diseases needing medical treatment (e.g. high blood pressure, diabetes mellitus type II) and two thirds suffered from musculo-skeletal diseases.

During the training period, six people dropped out for health reasons. Thus, a total of 19 participants completed the program (15 women, four men; mean age: 83.5; range: 75–91). All subjects originally lived in the surroundings of Innsbruck, a city with 120,000 inhabitants. Three women were single, one divorced and 11 widowed. Of the males, one was married, one divorced, and two widowed. Six people had attended elementary schools, nine had attended secondary modern schools, and four had attended grammar schools. Only 16 subjects were still available at t_3; two were severely ill and one had died (13 women, three men; mean age: 84.7; range 75–91).

Procedure

The study used a longitudinal design. After an initial psychometric test battery for investigating suitability for study participation (t_1), the computer-assisted cognitive training program (CAT) was carried out over 14 weeks and consisted of one 45-minute session per week. The psychometric test battery was administered again immediately after completion of the training program (t_2) and then five months later (t_3). The test battery was designed to assess fluid intelligence and consisted of indices of:

1. Information processing speed: that is speed and attention, with which new information is picked-up, mostly operationalized on the basis of perceptual psychomotor speed.
2. Short-term memory: including primary memory (storing cues for some seconds) and secondary memory (storing cues between 30–60 seconds).
3. Long-term memory (up to 30 minutes and longer).
4. Interference tendency: that is a tendency to mix-up similar codes, a possible reason for the forgetting process.

5. Learning: elderly people need more rounds of learning to meet the learning criteria. This uses up available cognitive capacity and permits less information uptake (Hüppe, 1998).

The individual cognitive tests (all of which are widely regarded as being reliable and valid) were as follows:

The California Verbal Learning Test (Delis et al., 1987. German version: Münchner-Verbaler-Gedächtnis-Test by Ilmberger, 1988). This instrument tests short- and long-term verbal memory, learning, and interference tendency. Learning is assessed by monitoring performance on an immediate recall task over the course of three identical trials where the stimuli to be remembered are 12 orally presented words. After this task, a further list of 12 words is presented orally for immediate recall and is followed by an instruction to recall the original list from the learning task. Recall of the initial list serves as another index of recall performance, recall of the list used in the learning task serves as an index of interference tendency with disturbances in recall of the original list by words in the second list indicating the extent of interference. At this stage in the task categories can be given as an aid to recall of the original list (e.g. 'what belongs to the category fruit?'). For assessing long-term memory, subjects are asked to recall the words in the first list (including category formation) after a delay of 30 minutes.

Nürnberger-Aging-Inventory (NAI; Oswald & Fleischmann, 1986). The NAI is the most widely used instrument for assessing cognitive functions in older people in German-speaking countries. The test contains 11 sub-tests that assess both memory and cognitive speed; out of these, the following six were used in the present study:

- *Trail making test.* As a test of information processing speed. Numbers randomly positioned on a printed page have to be sorted by numerical value as quickly as possible by connecting them with a line using a pencil.
- *Repeat sentences.* Immediate free reproduction of sentences of increasing length. Assesses short-term passive attention ability (primary memory) for meaningful verbal material.
- *Word lists.* Immediate and delayed free recall and recognition of words. Assesses both verbal capacity of secondary memory (verbal encoding, degree of consolidation) and long-term memory (up to 30 minutes).
- *Word pairs.* Association of pairs of words and reproduction after four repetitions. Verbal association and reproduction (secondary memory).
- *Picture test.* Immediate and delayed free recall of pictures of objects that are in daily use (e.g. an iron). Assesses visual secondary and long-term memory (up to 30 minutes).
- *Figure test.* Immediate recognition of geometrical figures. Short-term visual memory excluding semantic encoding, visual learning capacity (secondary memory).

Subjectively experienced aging process was assessed by a sub-section of the NAI which asked participants to judge their ability to carry out activities of daily living and to rate their general physical and intellectual condition and degree of independence.

Computer-assisted cognitive training

The study used 'Cognition I' (version 3.93) developed by Marker (1992) which includes tasks that are designed to increase attention, visuo-motor performance, reaction time, vigilance, attentiveness, memory, verbal performance and general knowledge. Out of the 56 exercises 12 were chosen to train the most important cognitive functions. Several of these exercises mimic real-life tasks and thus help to avoid boredom and increase motivation. Marker (1992) points out that occasional failures probably improve motivation while more prolonged or consistent failures often cause participants to drop out of the training program. Taking into consideration the cognitive level of the participants (as shown in the psychometric results prior to training, t_1) the program was tailored to suit each individual. Easy tasks with guaranteed success were interspersed with more difficult tasks so that on the one hand, the danger of high frustration levels was avoided, and on the other, boredom with the tasks at hand. In order to maintain a high level of motivation, exercises were chosen in accordance to the preferences of the subjects. Table 1 shows the exercises employed, their contents, and training objectives. Statistical evaluation of the cognitive parameters (comparison of t_1, t_2 and t_3) was carried out with the Wilcoxon (T) signed ranks test.

Results

When comparing performance pre-training and immediately post training (t_1/t_2), significant improvements were observed in the majority of cognitive functions. Verbal and visual, secondary and long-term memory, information processing speed, learning, and interference tendency improved significantly (Tables 2a and 2b).

After the training, it was easier for the participants to remember word-pairs and lists of words immediately and also 30 minutes later. There was also a corresponding improvement in the retention of visual material (recognizing pictures of objects). In addition, perceptual psychomotor speed and information processing speed also showed improvement.

TABLE 1. Computer exercises employed in cognitive training

Exercise	Contents	Objective
Anagrams	To build a meaningful German substantive from a given set of letters	Training for dealing with meaningful linguistic material at the level of simple words
Succession	Continuously check whether the day (month/year) now shown immediately follows the one shown just before	Training for speed and stress-coping
Reading	A text is read and questions are asked about details of the text	Training memory functions
Point-by-point	Numbers to be connected line by line	Attention, visuo-motoric coordination
Arithmetic	Simple calculation performed in the head. Addition, multiplication and subtraction	Trains automatism, such as the multiplication table
Division	Lines should be divided in two equal parts	Training in spatial perception
Clock	An analogue clock is to be read and set	Trains flexibility, perception and concentration

TABLE 2a. Cognitive parameters (information processing speed, interference tendency, learning) at the three time points of measurement

	Pre-training t_1		Post-training t_2		5-month follow-up t_3	
Psychometric test	Mean ± SD	Comparison t_1/t_2	Mean ± SD	Comparison t_1/t_3	Mean ± SD	Comparison t_2/t_3
Information processing speed						
NAI, Trail Making Test, 1st run	84.1 ± 69.7	(0.054)	63.5 ± 47.6	NS	66.1 ± 31.4	NS
NAI, Trail Making Test, 2nd run	72.1 ± 48.4	0.011	59.5 ± 43.7	NS	61.4 ± 37.7	NS
NAI, Trail Making Test, average time (in min.)	78.1 ± 58.0	0.179	61.5 ± 44.7	NS	63.8 ± 34.0	NS
Interference tendency						
CVLT, interference list	3.4 ± 1.9	0.003	5.3 ± 2.2	0.047	5.9 ± 7.4	NS
Learning						
CVLT, learning curve, 1st run	3.3 ± 1.4	0.001	4.9 ± 1.4	0.002	5.0 ± 1.6	NS
CVLT, learning curve, 2nd run	5.2 ± 1.9	0.001	7.4 ± 1.8	0.002	6.9 ± 1.9	NS
CVLT, learning curve, 3rd run	6.6 ± 2.0	0.001	8.8 ± 2.2	0.006	7.9 ± 1.9	NS

The ability to learn verbal material improved to a marked degree and the tendency to mix up similar codes was significantly reduced. Learning and interference tendency were found to be significantly better five months after the end of the training program than before it started (t_1/t_3) indicating that the effects of the program were relatively long-lived (Table 2a).

There were no noticeable effects of cognitive training on the self-rating scales measuring mood and subjectively experienced aging. Thus, the participants did not report carrying out more daily activities than before or a higher degree of independence.

Discussion

The elderly populations of many developed countries are expanding rapidly and increasingly medical practice is being called upon not only to deal with the treatment of illnesses in older people, but also to begin 'geroprophylaxis'—preventive therapy specifically aimed at older people (Steinhagen-Thiessen *et al.*, 1992).

Self-reporting of cognitive impairment, such as increased forgetfulness and decreased concentration are relatively commonplace in older people and are often regarded as being 'part of normal aging', this in part, may be due to the perception that cognitive decline is irreversible and not amenable to treatment. The results of the present pilot study, however, suggest that this is not necessarily the case and that computer-assisted cognitive training may offer a means of improving benign age-associated cognitive deficits in older people and that to some extent the benefits of such training may be long lasting.

The design of the program encompassed training for multiple aspects of cognition including information processing speed, attention, memory, perception, and flexibility, in other words, various aspects of fluid intelligence.

Similar to the results of Ott-Chervet *et al.*, (1998), after undergoing training, it was easier for our participants to remember lists of words, word-pairs and also pictures even 30 minutes later. Information was grasped and processed more speedily; such speed is a basic precondition for higher cognitive functioning. There was a marked improvement in learning verbal material, and the tendency for interference, a cause of memory loss, could be counteracted to some extent. In addition it was noted that improvements in learning and interference tendency were retained for at least five months after the end of the training program.

Table 2b. Cognitive parameters (primary memory, secondary memory/short-term memory, long-term memory) at three time points of measurement

Psychometric test	Pre-training t_1		Post-training t_2		5-month follow-up t_3	
	Mean ± SD	Comparison t_1/t_2	Mean ± SD	Comparison t_1/t_3	Mean ± SD	Comparison t_2/t_3
Primary memory (verbal)						
NAI, repeat sentences	37.1 ± 4.7	(0.057)	39.1 ± 3.7	NS	37.9 ± 4.6	NS
Secondary memory/short-term memory (verbal)						
NAI, word lists, free recall, 1st run	4.4 ± 1.3	0.162	4.9 ± 1.0	NS	4.4 ± 1.7	NS
NAI, word lists, recognition, 1st run	6.3 ± 1.2	(0.083)	6.8 ± 1.0	NS	6.9 ± 0.9	NS
NAI, word pairs	9.5 ± 3.2	0.008	12.3 ± 3.0		9.1 ± 3.7	0.010
CVLT, recall of the 1st word list	3.0 ± 2.4	0.019	5.1 ± 2.7	(0.099)	4.1 ± 3.7	NS
CVL, recall of the 1st word list with memory aids (categories)	6.4 ± 1.9	0.003	8.4 ± 2.0	NS	7.1 ± 2.7	NS
Secondary memory/short-term memory (visual)						
NAI, picture test, 1st recall	4.7 ± 1.1	0.009	5.8 ± 1.2	NS	5.0 ± 1.2	0.034
NAI, figure test	8.4 ± 2.0	0.021	9.5 ± 2.2	NS	8.9 ± 1.9	NS
Long-term memory up to 30 min. (verbal)						
NAI, word list, free recall after 30 min., 2nd run	1.7 ± 1.7	0.033	2.9 ± 1.8	NS	1.7 ± 2.3	(0.051)
NAI, word list, recognition, 2nd run	5.6 ± 2.1	(0.056)	6.7 ± 1.1	NS	6.2 ± 1.3	(0.092)
CVLT, recall of the 1st list after 30 min.	3.2 ± 2.5	0.000	6.3 ± 2.5	(0.079)	4.6 ± 3.6	(0.071)
CVLT, recall of the 1st list with memory aids (categories)	6.3 ± 2.2	0.000	9.7 ± 1.9	NS	6.9 ± 3.4	0.028
Long-term memory up to 30 min (visual)						
NAI, picture test, 2nd recall	3.4 ± 1.5	0.009	4.6 ± 1.1	NS	3.5 ± 1.0	(0.037)

These results underline once again that the learning ability of older people should not be under-estimated and that one should be aware of overprotection and reducing challenging learning situations, since these result in 'learned helplessness' and impairment of cognitive functional ability because of non-use (Weinert, 1995).

Those cognitive parameters, which remained unchanged over the period of our investigation might also, hypothetically, imply a therapy effect, since in people of such an advanced age, worsening of cognitive abilities can be expected in the course of nine months. However, this supposition can be verified only by evaluation of a control group of 'untreated' subjects. After consultation with the director of the Home, this approach was not pursued since it was feared that persons in the control group 'not allowed to work at the computer' might feel that they were being discriminated against and devalued.

In the present study participants were given a set of broad-based exercises to practise and individuals were allowed to choose those of the exercises that they particularly liked to do. Thus, the emphasis was not laid on the training of specific deficits. In the future, computer training for healthy old people might include exercises directed at improving specific deficits in addition to those that they prefer to do, in other words, individually tailored programs.

In our study, the training program did not have any effects on the participants' mood or subjectively experienced aging. This might be due to the selection of the subjects, as it can be assumed that those who participated in the training program were those who had a rather positive attitude to the aging process. To be realistic, in the future it will be precisely this group of aged individuals that will participate in such computer programs (Gunzelmann *et al.*, 1996) so it may be beyond the bounds of cognitive training to influence mood. Nevertheless, comments such as 'the training distracted my mind from pain' or 'my grandson was quite surprised that I too can do it' show that quite apart from improvements in cognitive abilities, the training had some positive psychosocial effects.

There were very few difficulties in carrying through the cognitive training program, a finding, which is in agreement with those of other reports (Bodenburg & Technow, 1992; Hofmann *et al.*, 1995). It was also found that special exercises were helpful in teaching participants to learn how to use the mouse or the keyboard, with the following instruction appearing on the monitor, for example: 'press the cursor arrow up, then right, then left, then down'. In another exercise a square divided into four fields appears on the monitor followed by the instruction: 'move the mouse and click on the field in the above right (left) corner'.

Special attention had to be paid only to sensory impairments, but it was often enough just to adjust the distance between the eye and the monitor in order to correct visual problems. The high level of acceptance and openness of the subjects to the computer surprised us. Before and after the training, all participants were asked about their attitude to the computer. Two of them expressed the fear that they might not succeed in learning their way about the computer, but nonetheless wanted to try it out. After the training, all of the participants were enthusiastic about the program and definitely wanted to continue with it. In the meantime, CAT has acquired a firm place in the residential home and is currently under the direction of an occupational therapist.

In summary, this study shows that employing the modern technological medium of a computer may usefully be employed in the prophylaxis of age-associated cognitive decline. By providing instant, value-free feedback, the computer permits the user to make an immediate objective comparison with data collected earlier and thus helps in setting up a systematic training plan. In this sense, computer-assisted methods of cognitive training are better than the traditional ones.

If we keep in mind that that the average age of the participants in this study was high, one can justifiably expect that the training program would also have success in persons who are somewhat younger. It may therefore be worthwhile to investigate whether cognitive losses can be prevented by integrating computer-assisted training programs in everyday activities (home training) at an earlier stage, for instance soon after retirement.

To live according to the principle of 'use it or lose it' (Swaab, 1991) also makes sense against the background of the longitudinal study of La Rue and Jarvik (1987). In this study it was reported that patients with dementia started to lead a markedly more passive and inactive life 20 years earlier than healthy persons. Other authors emphasized the importance of physical activity and leisure-time activities too (Huppert, 1991). As the present pilot study used no comparison group, future research could usefully compare the computer-assisted cognitive training with other forms of activation (such as physical therapy, reactivating occupational therapy or resistance training, Bach *et al.*, 1995; Perrig-Chiello *et al.*, 1998). Once the relative efficacy of different forms of mental and physical stimulation had been established, research could also be further extended to investigate if the use of combined training modalities could potentially be more effective than a single training regime in isolation.

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