Successful Cognitive Aging:

Executive functioning, determinants, and interventions

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Proefschrift

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Contents

Chapter 1

Introduction

At present, 16% of the European population is 65 years or older. This proportion expected to rise to 27% in 2050 (Beets, 2000). This increase is due to the post World War II 'baby boom' and the prolonged life expectancy of recent generations. With respect to the demographic changes with increasing number of older people, it is expected that problems in old age also increase (e.g. Kriegsman, Deeg, & Stalman, 2004; Van Boxtel et al., 1998). For this reason, it is important that gerontology shifts its focus from life extension to improvement of quality of life (e.g. Fries, 1990). A large group of older adults develop diseases typically associated with old age and may experience disability and diminished autonomy. Still, at least 81% of individuals aged 65 years and older do not have a disease or disability that profoundly impairs their functioning in every life (Melzer, McWilliams, Brayne, Johnson, & Bond, 1999; Ostchega, Harris, Hirsch, Parsons, & Kington, 2000). In 1987, Rowe and Kahn (Rowe & Kahn, 1987) proposed that the aging covers a spectrum ranging from pathological aging, through usual aging, to successful aging. They state that, successful aging is a multidimensional process, involving a low probability of disease and disease-related disability, a high level of cognitive and physical functioning, and an active engagement with life (Rowe & Kahn, 1997).

The influential notion of Rowe and Kahn has stimulated research on successful aging in the past decade. Yet, data regarding 'successful cognitive aging' are sparse, which is unfortunate because many older people complain about their cognitive functioning (Commissaris, Ponds, & Jolles, 1998; Ponds & Jolles, 1996). Empirical evidence is needed with respect to the determinants of successful cognitive aging and about possible interventions to optimise the course of the cognitive aging process. The research described in this thesis was intended to contribute to this knowledge base. This Chapter presents the background for the problem and the aims of the research in this thesis. Evidence on the nature of cognitive decline, and in particular executive functioning, in old age is summarised in the following section. The next paragraph provides evidence on the factors that may be involved in successful cognitive aging. Finally, background information is provided on the possibility to improve or maintain cognitive functioning, well-being and quality of life in order to support successful aging. The objectives of this thesis and an outline of the studies described in this thesis are presented at the end of this Chapter.

Cognitive aging

It is well established that people's objective performance on cognitive tests declines with age (Rabbitt, Bent, & McInnes, 1997; Schaie, 1994; Verhaeghen & Salthouse, 1997) and that the subjective appraisal of cognitive functioning by older persons changes. More than 50 percent of older people complain about forgetfulness and have less confidence in their cognitive functions (Ponds, Commissaris, & Jolles, 1997). In a meta-analysis, it was demonstrated that performance on reasoning, speed, and episodic memory tasks was 0.7 to 1.5 standard deviation lower in adults aged over 50 years than in individuals aged 50 or younger (Verhaeghen & Salthouse, 1997). Likewise, strong evidence for an age-related cognitive decline was demonstrated in longitudinal studies (Christensen et al., 1999; Schaie, 1994). Several cognitive aging theories have been proposed to explain why cognitive functions tend to decline as people age (Band, Ridderinkhof, & Segalowitz, 2002). First, the processing speed hypothesis has been quite authoritative and states that age-related cognitive decline can be attributed to a decrease in the speed with which elementary cognitive operations are executed. This decline in information processing speed places fundamental limits on most aspects of cognition (Earles, Connor, Smith, & Park, 1997; Salthouse, 1996). Another, relatively recent hypothesis highlights the fundamental role of executive functioning in cognitive aging. This relatively new notion is challenging, because it relates the nature of objective deficits in cognitive performance to underlying neuropsychological dysfunctions and is compatible with the growing knowledge of brain function (Miller & Cohen, 2001). The basic idea behind this theory is described in more detail below.

Executive functioning

Executive functioning is defined as the capacity that enables a person to engage successfully in independent, purposive, self-serving behaviours (Lezak, 1995). It has been conceptualised as a super-ordinate cognitive capacity, a top-down system sub-serving several basic cognitive domains (Baddeley, 1998; Shallice, 1982). Executive functions enable people to state and perform goals, deal with novel conditions, solve problems, adapt to unexpected circumstances, and perform multiple tasks at the same time. For this reason, this cognitive domain is considered a major prerequisite for functioning in daily life (Cahn-Weiner, Boyle, & Malloy, 2002; Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998). Neuropsychological studies of patients with frontal lobe damage and neuro-imaging studies indicate that this domain may be associated with the prefrontal cortex (West, 1996). Through the years, many researchers have used the term ‘frontal functions’ in a metaphorical way to denote this cognitive domain without reference to the anatomical structure (Burgess, 1997).

Interest in executive functions has increased rapidly in the last three decades. This is because of a greater awareness of the neuroanatomical basis and the importance of the efficiency of executive control functions in determining the performance on other cognitive tasks (Luszcz & Bryan, 1999; McDowd & Shaw, 2000; Salthouse & Miles, 2002). Strangely enough, a coherent theory and a clear operationalisation of these functions are still lacking.

Three subordinate functions are often suggested to be part of the executive domain: 'set shifting' (e.g. shifting between tasks), 'working memory', and 'inhibition of irrelevant responses' (Miyake et al., 2000). Task execution can fail if the working memory is not updated and the content of working memory can yield conflicting output if irrelevant information is not removed or inhibited and if relevant information is not activated in time (Baddeley, 1998; Band et al., 2002). Attentional functions as well as functions related to behavioural planning and organization are also regarded as important executive functions (Lezak, 1995).

Executive functioning and aging

As people age, executive functions appear to be compromised (e.g. Andres & van der Linden, 2000; Bryan & Luszcz, 2000). This age-related decline is important because executive functioning may be a central feature of everyday functioning among older adults (Grigsby, Kaye, Kowalsky, & Kramer, 2002) and may even have implications for successful aging (Rowe & Kahn, 1997). As a result of changes in executive functioning, older people may experience difficulties in planning leisure-time activities after retirement, in managing their finances, or in coping with novel situations. Moreover, societal changes are often challenging for older people and may cause problems in learning and applying new strategies and procedures, such as using computers and mobile phones. In the past few decades, neurobiological and neuropsychological studies have demonstrated that these executive functions may be one of the first cognitive domains to deteriorate with age. Neurobiological studies have demonstrated that the frontal lobes are more sensitive than other parts of the brain to the aging process (Raz et al., 1997; Salat, Kaye, & Janowsky, 1999; Tisserand et al., 2002). This region shows a greater loss of volume with age than do other cortical areas, and the volume loss is paralleled by a local decrease in the number of synapses, atrophy of dendritic processes, and reduced efficiency in cellular mechanisms that support the synthesis and transmission of neurotransmitters (West, 1996). Neuropsychological evidence suggests that older adults perform substantially worse than younger adults on tasks measuring executive functioning (Bryan & Luszcz, 2000, 2001; Mayr, Spieler, & Kliegl, 2001; Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000). The convergence of the neuropsychological and neurobiological lines of evidence has resulted in the frontal lobe hypothesis of aging, which states that cognitive abilities supported by the prefrontal cortex show signs of age-related decline at an earlier age and to a greater degree than cognitive abilities supported by other brain structures (West, 1996). This frontal lobe hypothesis of aging is regarded as an alternative to the above-mentioned hypothesis concerning reduced speed of information processing (Earles et al., 1997; Salthouse, 1996).

Determinants of cognitive aging

One of the most striking findings in the literature on aging is that the rate of cognitive decline varies considerably between individuals and that this variation tends to increase as people age (Christensen et al., 1999), with some individuals performing as well as young adults and others showing a decline for many years. The challenge of cognitive gerontology today is to identify biological and psychosocial factors that may help to explain these individual differences in cognitive decline. Biological factors, such as hypertension, diabetes, and sensory functioning, have been demonstrated in cross-sectional studies to be associated with poor cognitive functioning in an older population (Cervilla, Prince, Joels, Lovestone, & Mann, 2000; Houx & Jolles, 1993; McNeal et al., 2001; Van Boxtel et al., 1998). Likewise, psychological and social factors, such as depressive symptomatology and less emotional support, are thought to have the potential to adversely influence the cognitive functioning of older adults (Bosma et al., 2002; Den Hartog, Derix, van Bemmel, Kremer, & Jolles, 2003; Seeman, Lusignolo, Albert, & Berkman, 2001). Unfortunately, most studies that investigated the determinants of cognitive aging had a cross-sectional design, and thus do not enable inferences about cause and effect. Longitudinal studies that specifically addressed the determinants of cognitive aging still are scarce (Baltes & Baltes, 1990; Schaie & Hofer, 2001). The Maastricht Aging Study, a large longitudinal study on cognitive aging (Jolles, Houx, van Boxtel, & Ponds, 1995), has enabled the investigation of determinants of age-related cognitive decline such as prevalent diseases (Van Boxtel et al., 1998), memory self-efficacy (Ponds & Jolles, 1996), exposure to toxic substances (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2000), or engaged lifestyle (Bosma et al., 2002). The database of MAAS is well equipped to investigate various biological, psychological, and psychosocial determinants of successful cognitive aging. It is imperative to perform this type of research because it may contribute to the identification of factors that may potentially be modified as part of dedicated intervention programmes.

Interventions in older individuals

Executive functioning

As a consequence of the growing number of older people and who wish to remain active members of society and keep a good quality of life (Fries, 1990), there is a need for intervention studies aimed at the promotion of successful aging. Major research questions concern the improvement or maintenance of cognitive performance and how to positively affect quality of life and well-being, thereby promoting successful aging. Although a whole range of interventions to improve cognitive functioning in older people have been developed in recent years, only a few of these interventions have been empirically evaluated. In the last decades, there have been some studies, which demonstrated that neuropsychological interventions in older adults may have positive effects on cognitive functioning or quality of life (e.g. Ball et al., 2002; Lachman, Weaver, Bandura, Elliott, & Lewkowicz, 1992; Woolverton, Scogin, Shackelford, Black, & Duke, 2001). Unfortunately, many studies have methodological limitations, such as absence of a control group (Caprio-Prevette & Fry, 1996) or a small sample size (low 'power') (Rasmusson, Rebok, Bylsma, & Brandt, 1999; Rebok, Rasmusson, Bylsma, & Brandt, 1997). In addition, quite some studies are characterized by flaws in the design or in the use of the psychometric instruments both in the training and in the assessment of the outcome (Brooks, Friedman, Pearman, Gray, & Yesavage, 1999). The stage is set to evaluate interventions for older adults using controlled trials, in a similar fashion as in pharmacological studies. Most cognitive interventions for older adults address memory functioning and memory self-efficacy (e.g. Lachman et al., 1992; Valentijn et al., in press). No study has yet evaluated an intervention for older adults that focuses on executive functioning. This is unfortunate because this cognitive domain may be involved in various activities of daily life and shows a profound worsening of function with increasing age.

Hearing functioning

Apart from this cognitive intervention, there is a special place for interventions that focussed on the improvement of a non-cognitive age-related variable with potential impact on cognitive function in older adults. A major example concerns elderly subjects with a hearing defect, which affects at least 30% of people aged 65 years and older (Cruickshanks et al., 1998). A reduced efficiency of the sensory systems has been related to a reduced efficacy of the neural networks involved in cognitive abilities, for example, through a loss of synaptic connectivity or neuronal atrophy (Lindenberger & Baltes, 1994; Sekuler & Blake, 1987). This age-related phenomenon may thus be as a risk factor for deterioration of cognitive functions due to prolonged lack of adequate sensory input, which may reduce the opportunities for intellectually stimulating exchanges with the environment. Conversely, if sensory functioning can be improved, a qualitatively better and richer auditory input may promote reconnection of neural circuits in the brain and result in a better cognitive performance. It can therefore be hypothesised that conventional treatment of hearing impairment (by means of hearing aids) may have a positive influence on cognitive functioning and well-being. Indeed, previous observational studies of older people have shown that sensory functioning is related to both quality of life and cognitive functioning (e.g. Lindenberger & Baltes, 1994, 1997). For example, in the Berlin Aging Study, reduced sensory functioning was associated with poor performance on cognitive tests in adults aged 70 years and older (Lindenberger & Baltes, 1994). Likewise, Strawbridge et al. (2000) showed that physical, mental, and social functioning decreased with increasing severity of hearing impairment (Strawbridge, Wallhagen, Shema, & Kaplan, 2000). Although hearing impairment in old age appears to be associated with decreased cognitive functioning and well-being, few studies have systematically investigated the effects of interventions to improve auditory functions on cognition and quality of life.

Objectives of the thesis

The research described in this thesis has two main objectives. The first is to study age-related differences in cognitive performance and to investigate potential determinants of successful cognitive aging in a longitudinal follow-up study, with a special emphasis on executive functioning. The second objective is to examine the effects of specific interventions in older adults on the cognitive functioning, well-being, and quality of life. The first intervention concerns primarily executive functions and the second is directed at auditory functioning. The studies presented in this thesis can be considered complementary to the studies discussed in the thesis of Susanne Valentijn[1], which also addressed successful cognitive aging. This thesis primarily covers memory functioning and visual functioning in the context of successful aging. The studies described in both theses were part of a large research programme entitled "'Successful ageing, cognitive ageing and experimental intervention studies related to the Maastricht Ageing Study (MAAS)" (NWO: 014-91-047).

The outline of the thesis

The thesis consists of two sections. In part one, cognitive functioning in old age and the determinants and consequences of successful cognitive aging were investigated, using data from the Maastricht Aging Study. In part two, the effects of (cognitive and sensory) interventions in older adults were evaluated on the cognitive functioning, well-being, and quality of life. The results of the studies described in this thesis are jointly discussed with respect to methodology, theoretical, and practical implications in Chapter 9.

Part I

The goal of the study presented in Chapter 2 was to investigate whether differences between age groups are identical for various cognitive functions, including attention, executive functioning, and memory functions, or whether age-related differences are more pronounced

[1] Valentijn, S. (2004) *Succesful cognitive aging: memory, determinants, and interventions.* Doctoral Thesis, Maastricht University, Maastricht

for particular cognitive domains. The influence of two important age extrinsic factors, education and sex, on cognitive functioning was also examined.

Cognitive decline is not only associated with age, but also with factors that may to some extent be amenable to modification. However, few studies have examined the contribution of such biological and psychosocial factors to the relationship between age and cognition, particularly with respect to executive functions. In the study presented in Chapter 3, we examined a set of biological and psycho-social factors that emerged from the cognitive aging literature as possible explanation for the differential cognitive decline, particularly executive functioning, in older adults.

In the third study (Chapter 4), we examined whether different dimensions of health status (physical, psychological, and social functioning) are differentially related to actual cognitive functioning, including executive functioning and to cognitive change over a 6-year period in a large sample of individuals aged 60 years or older.

Some authors have suggested that cognitive functioning, especially executive functioning, has a direct impact on functional status in older adults and may influence independent living. However, few studies have investigated whether cognitive functioning actually does affect functional status. For this reason, we investigated in Chapter 5 the direct and long-term impact of cognitive functioning on functional status in an older population.

Part II

Executive problems appear to be an important contributor to everyday functioning among older adults. Although many older adults experience these difficulties, no study, so far, has evaluated neuropsychological interventions that focus on these cognitive functions in older adults. In the study reported in Chapter 6, we investigated whether an intervention for older adults directed at executive functions has positive effects on cognitive complaints and cognitive functioning.

In the same vein, we undertook an intervention study to examine the potential impact of hearing aid use on cognition and quality of life. In a controlled study, first-time hearing aid users were compared with adults with a comparable hearing impairment but who did not use a hearing aid. In Chapter 7, it was examined whether the cognitive performance of older adults may benefit from rehabilitation with hearing aids. The subsequent Chapter 8 is devoted to the non-cognitive effects of hearing aid use, i.e. the quality of life, depressive symptoms, physical functioning, social functioning, and subjective auditory functioning.

Finally, in Chapter 9 findings of the studies are combined and are discussed with respect to methodological considerations, practical implications and theoretical implications.

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Part I

Determinants

Chapter 2

Cognitive functioning in healthy adults: A cohort study into the effects of age, sex, and education

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Abstract

The objective of this study was to determine a possible differential effect of age, education, and sex on learning, working memory and cognitive speed in healthy older adults. A group of 578 healthy participants in the age range of 64-81 was recruited from a large population study of healthy adults (Maastricht Aging Study). Even in healthy individuals in this restricted age range, there is a clear age-related decrease in performance on learning, memory and cognitive speed tasks. The capacity to inhibit information is affected most. Education had a substantial effect on cognitive functioning: participants with a middle or high level of education performed better on cognitive tests than did participants with a low level of education. Women performed better than men on memory tasks. Therefore, education and sex must be taken into account when examining an older individual's cognitive performance.

Introduction

Many studies have demonstrated that certain cognitive functions diminish with increasing age. Information processing speed is compromised (Houx & Jolles, 1993; Jolles, Houx, Vreeling, & Verhey, 1993), as is efficient consolidation of newly learned information (Salthouse, 1998). In addition, problems appear in executive functions such as planning and behavioural organisation (Bryan & Luszcz, 2000; Craik & Salthouse, 2000). Until now, it is not clear whether these cognitive functions decline at the same rate or whether there is a differentiation between cognitive domains. Some authors have suggested that especially executive functions may be the first to deteriorate (Jolles, 1986; West, 1996), whereas others have suggested that the age-related decline in cognitive functions, including executive functions and memory, is due to a general decline in processing speed (Salthouse, 1996; Verhaeghen & Salthouse, 1997).

Most research on cognitive ageing has compared groups of young adults (often in their 20s) with groups of older adults (often ranging from late 60s to the 80s; Craik & Salthouse, 2000). Unfortunately, studies, which have used a broad age-range of participants, are limited by cohort effects (Schaie, 1994; Schretlen et al., 2000). In the present study, we included a small age range (64-81 years) in order to minimise cohort effects. It is important to evaluate a possible deterioration within this age range because most people aged 65 and older consider themselves relatively healthy and wish to continue to participate in society and maintain a good quality of life. It is however not known which factors determine age-related cognitive differences, apart from diminishing health (Houx & Jolles, 1993; Van Boxtel et al., 1998). In addition, little is known about how educational level or even a person’s sex affects their cognitive function in this age range. As the proportion of older people is increasing rapidly in the developed world, it is imperative to evaluate the possible influence of such factors. This is because the factors ‘age’, ‘education’, and ‘sex’ could have differential effects on cognition within the group of older adults. If so, this knowledge could add to our insight with respect to normal versus successful ageing (Rowe & Kahn, 1987).

Earlier research has shown that health-related factors and psychosocial factors, such as lifestyle, appear to affect the cognitive performance of otherwise healthy individuals (Bosma et al., 2002; Elwood, Pickering, & Gallacher, 2001; Houx & Jolles, 1993; Van Boxtel et al., 1998). In addition, a higher level of education appears to be a strong predictor of sustained cognitive function in old age and may protect against age-related decline (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2003; Elias, Elias, D'Agostino, Silbershatz, & Wolf, 1997; Evans et al., 1993; Lyketsos, Chen, & Anthony, 1999). Interestingly, among people aged 85 years and older, women have better scores for cognitive speed and memory tasks than do men despite their often lower level of formal education (Van Exel et al., 2001). These findings were based on either very old persons or the studies used a very broad age-range (e.g. from 18 to 71 and older (Lyketsos et al., 1999)).

Thus more needs to be learned about the possible differential effects of age on the major cognitive domains of cognitive speed, executive functions, memory and learning in healthy older people. In addition, the influence of education and sex in this age group should be evaluated, given their influence over a larger age range or in an older population (e.g. Farmer, Kittner, Rae, Bartko, & Regier, 1995; Van Exel et al., 2001). More information with respect to the effects of age, education, and sex on cognitive functions could be important for planning interventions for healthy older adults and give them insight into the factors that determine their cognitive performance and which could contribute to successful ageing.

We investigated whether differences between age groups are similar for various cognitive functions, such as attention, executive functioning, and memory functions which are especially sensitive to ageing or whether age related cognitive differences are more pronounced in specific domains (i.e. executive functions or processing speed). In other words, are there domain specific or more general differences in cognitive function? We hypothesised that while there are general age-related cognitive differences with advancing age, executive functioning is especially affected because the frontal cortex, which supports these functions, is one of the first areas of the brain to malfunction in normal ageing (Jolles, 1986; Tisserand, 2003). We also investigated the influence of education and sex on cognitive functioning. The study was performed using data from The Maastricht Aging Study (MAAS), a large healthy population study involving 1823 healthy participants. The MAAS has an advantage over earlier studies in that the sample is stratified at first occasion according to age, sex, and occupational activity, which produces equally reliable estimates of population parameters across all levels of the age variable, in both gender, and in a low versus high level of occupational activity.

Methods

Participants

The data used in the present study were derived from the Maastricht Aging Study (MAAS), a large-scale population study examining determinants of cognitive ageing. The aim, population characteristics and design of MAAS are reported elsewhere (Jolles, Houx, van Boxtel, & Ponds, 1995). In short, participants were randomly recruited from a patient register of collaborating general practices in the south of the Netherlands (Registration Network Family Practices (Metsemakers, Höppener, Knottnerus, Kocken, & Limonard, 1992)). These men and women, aged 24 to 81, were without documented medical conditions known to interfere with normal cognitive function (e.g. dementia, mental retardation, and cerebrovascular pathology). The sample was stratified according to age (12 groups; ranging from 25 ± 1, 30 ± 1, 35 ± 1,…, 80 ± 1 years, mean age 51.4 (sd 16.8) years), sex, and level of occupational activity (two levels). In the period 1993-1995, 1823 people were assessed regarding cognitive and physical measures. For the present study, data for participants in the four oldest age categories (i.e. 65 ± 1, 70 ±1, 75 ±1, 80 ± 1, age range 64-81 years) were used (n=578; 292 men, 286 women).

The Medical Ethics Committee of Maastricht University, the Netherlands, approved this study. All participants gave their written informed consent.

Measures

Independent variables

Age was used as a categorical variable; participants were grouped in four groups, namely, 65±1 years, 70±1 years, 75±1 years, and 80±1 years. Educational level was indexed on a three-point scale (low=elementary education and lower vocational education; middle=intermediate secondary education and intermediate vocational education; high=higher secondary education, higher vocational education, university education, and scientific education; De Bie, 1987). Sex was included as an independent variable.

Cognitive variables

In order to obtain more insight into cognitive functions in older individuals, several cognitive tests were administered to all participants.

The Stroop Colour Word Test (SCWT) involves three cards displaying a hundred stimuli each (Houx, Jolles, & Vreeling, 1993; Stroop, 1935). The first card contains colour words printed in black ink, which have to be read. The second card contains coloured patches, which have to be named. The last card displays colour names printed in incongruously coloured ink. Participants are instructed to name the ink colour of the printed words. By subtracting the time needed for the last part from the mean score of the first and second parts (SCWT-12), an interference score can be calculated (SCWT-i). This interference score can be regarded as a measure of inhibition of a habitual response, which depends on executive functioning (Hanninen et al., 1997; Miyake et al., 2000).

The Concept Shifting Task (CST) is a modified version of the Trial Making Test (Vink & Jolles, 1985). It consists of three parts. On each test sheet, 16 small circles are grouped in a larger circle. The smaller circles contain numbers, letters or both, appearing in a fixed random order. Participants are requested to cross out the items in the right order. In the last part, participants have to alternate between numbers (1-8) and letters (A-H). The time needed to complete each trial is scored. The difference between the last part and the mean score of the first and second parts (CST-ab) reflects the time for cognitive shifting (CST-i). Cognitive shifting or mental set shifting is considered a part of executive functioning (Miyake et al., 2000).

The Letter Digit Substitution Test (LDST) is a modified version of the Symbol Digit Modalities Test (Lezak, 1995; Smith, 1968). A code is presented at the top of a page, where a digit corresponds to a letter. The subject then has to fill in blank squares that correspond to the correct code. This test measures the speed and efficiency of operations in working memory.

The Visual Verbal Learning Test (VVLT) measures intentional learning and verbal memory (Brand & Jolles, 1985). Fifteen monosyllabic words are presented visually one after another and the subject is asked to recall as many words as possible. This procedure is repeated five times. Because of ceiling effects in the last two trails, the total score of the first three trials is used as dependent variable. After 20 minutes, delayed recall is tested. The VVLT measures the ability to learn and retrieve new verbal information from memory.

In the Verbal Fluency Test (Lezak, 1995), the subject is asked to produce as many words as possible in a given category (animals), within a fixed time. The variables of interest are the number of correctly named animals. The score can be seen as a measure for adequate, strategy-driven retrieval of information from semantic memory. Some researchers used this test to measure executive functions (Bryan & Luszcz, 2000; Persad, Abeles, Zacks, & Denburg, 2002).

Statistical analyses

Differences in demographic variables (i.e. sex and educational level) between age groups were analysed with Chi-square tests. A multivariate analysis of variance in which all independent variables were entered together (age class, sex, and education) was performed for each cognitive dependent variable. This analysis enabled us to examine the main effects of age, sex, and education. Furthermore, interactions between age on the one hand and sex or education on the other were explored. In order to compare the cognitive variables over the four age groups, the raw scores of all cognitive variables were transformed into Z-scores for the total group. Multivariate analysis of variance was performed using all cognitive measures. To compare age-related differences between cognitive measures, post-hoc contrast analysis was performed. In order to control the statistical error of multiple analyses, Bonferroni correction was applied, in which the alpha level (0.05) was divided by the number of statistical tests, where appropriate. Statistical analyses were performed using the SPSS program for Apple Macintosh, version 10 (SPSS-Inc., Chicago).

Results

The demographic characteristics of the study population are shown in Table 1. Chi-square tests showed that, as expected because of the applied stratification procedure, the age groups were comparable with respect to sex and education.

Table1. Demographic characteristics of the participants in the study by age groups

	65	**70**	**75**	**80**	**p-value**
N	164	166	173	75	
Sex (% man)	50.0%	51.8%	50.3%	49.3%	0.98
Education (1-3)					0.14
% low	59.8%	58.4%	60.5%	67.6%	
% middle	25.0%	25.9%	23.3%	9.5%	
% high	15.2%	15.7%	16.3%	23.0%	

Table 2 summarises standardised adjusted means of cognitive outcome measures by age group. Analysis of variance showed that the age groups differed significantly on all cognitive measures ($p<0.01$). In these tests, F-values were 4.4 or higher, indicating strong age-related differences.

Table 2. Adjusted means of cognitive performance by age-groups

	65	**70**	**75**	**80**	
N	164	164	169	72	
SCWT					
SCWT-12 [a]	53.8	54.0	57.8	59.5	***
SCWT-i [a]	53.5	61.0	67.0	86.7	***
CST					
CST-ab [a]	27.5	28.9	31.4	34.2	***
CST-i [a]	14.6	18.2	19.2	21.4	**
LDST	40.9	39.3	36.2	32.7	***
VVLT					
Immediate recall	21.1	19.8	18.2	16.1	***
Delayed recall	8.8	7.8	7.2	5.8	***
Fluency	22.7	21.7	20.2	19.8	***

Notes: SCWT= Stroop Colour Word Test; CST = Concept Shifting Task; LDST = Letter Digit Substitution Test; VVLT = Visual Verbal Learning Test.
[a] Higher scores reflect poorer performance
**$p<0.01$; ***$p<0.001$

In order to better illustrate the strong age-related cognitive differences, the differences in standardised cognitive performance were calculated for each age group, using the youngest age group as a reference group (Figure 1). Multivariate analysis including all cognitive measures (standardised) was performed in order to examine whether the performance of the various age groups was significantly different for the various cognitive measures. The main effect of type of test was not significant (F (7,524)=1.35, p=0.23), because of standardisation. The interaction between type of test and age group was significant (F (21,1568)=1.71, p=0.03). Specified contrasts showed that the differences between the age groups in verbal fluency (F(3,534)=3.08, p=0.03) and CST-i (F(3,534)=2.78, p=0.04) were significantly less pronounced than for the other cognitive measures. In contrast, the differences between the age groups in SCWT-i performance were significantly more pronounced than for the other measures (F(3,534)=2.96, p=0.03).

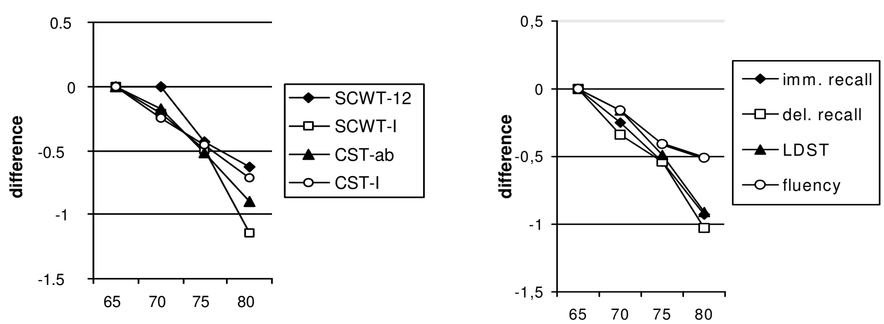

Figure 1. Differences in average standardised cognitive performance scores between the youngest age class and each subsequent age class.

In Table 3 the adjusted means of cognitive performance are presented by educational level and sex. For all cognitive domains, scores were higher for higher levels of educational attainment (p<0.01). F-values were 6.0 or higher for all tests. Scheffé post hoc tests revealed that participants with a middle or high level of education performed better than participants with a low level of education. The cognitive performance of individuals with a middle or high level of education was not different. This finding applied to most (SCWT-12, SCWT-i, CST-ab, VVLT, LDST, fluency), but not all (CST-i) cognitive tests (see Figure 2). A different pattern was found for sex. Women performed better than men on two cognitive outcome measures, namely, immediate recall (F(3,552)=35.20, p<0.01) and delayed recall (F(3,551)=47.98, p<0.01) of the verbal learning test. No sex differences were found for any of the other cognitive measures. There was no interaction between age and education or sex. F-values for interaction terms were 3.1 or lower.

Table 3. Adjusted means of cognitive performance by level of education and sex

	Education				Sex		
	Low	**Middle**	**High**		**Male**	**Female**	
N	348	132	96		292	286	
SCWT							
SCWT-12 [a]	57.7	53.9	51.5	***	56.7	54.9	
SCWT-i [a]	69.0	56.6	54.4	***	65.2	62.3	
CST							
CST-ab [a]	31.7	27.9	26.2	***	30.4	29.4	
CST-i [a]	19.9	17.5	11.1	***	17.6	18.1	
LDST	35.1	41.4	43.9	***	37.7	38.2	
VVLT recall							
Immediate recall	18.5	19.8	20.8	***	18.0	20.4	**
Delayed recall	7.3	8.1	8.2	***	6.9	8.5	**
Fluency	20.2	22.1	24.2	***	21.3	21.4	

Notes: SCWT= Stroop Colour Word Test; CST = Concept Shifting Task; LDST = Letter Digit Substitution Test; VVLT= Visual Verbal Learning Test.

[a] Higher scores reflect poorer performance

**p<0.01; ***p<0.001

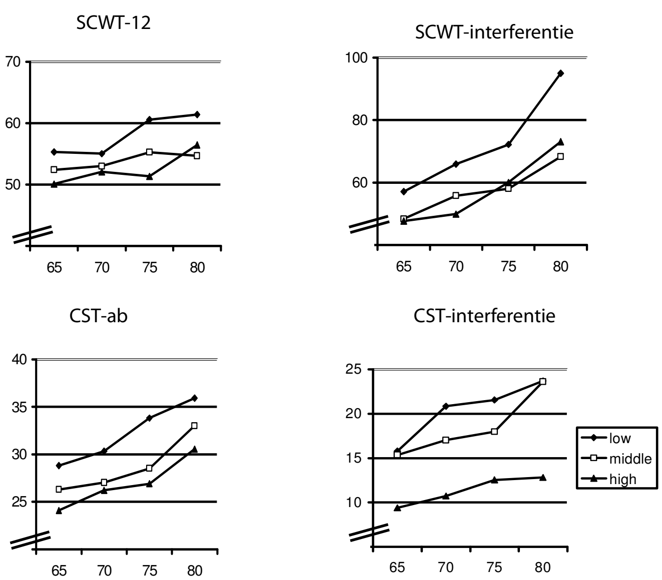

Figure 2. Performance on subtasks of Stroop Colour Word Test (SCWT) and Concept Shifting Task (CST) by level of education and age class

Discussion

The main aim of this study was to investigate whether the performance of individuals of different ages was similar or different for tasks tapping different cognitive domains. Results showed that there were age-related differences in cognitive functioning on the various measures of simple speed, complex speed, and memory. This supports the notion that there is a general decline in cognitive functioning over the studied age range. Interestingly, differences between age groups were most pronounced for a task with an inhibitory component. Because there is ample evidence that inhibition processes are an inherent component of executive functions (Hanninen et al., 1997; Miyake et al., 2000), the results suggest that there is indeed a differentiation in cognitive functions. It thus seems that most aspects of cognitive functioning decline with age and that some aspects, such as inhibition, decline at a faster rate. It is of interest to note that Zacks & Hasher (1997) suggested that the diminished ability to inhibit responses may explain the decreased memory performance across age groups. A reduced ability to inhibit responses can result in irrelevant information being retained in short-term memory, which hampers the storage of relevant long-term memory. Thus, a pronounced deterioration in inhibitory functions can be regarded as an important determinant of the well-known increased prevalence of memory complaints in the older people (Ponds, Commissaris, & Jolles, 1997). With respect to the other functions tested, it is clearly evident that there is a differentiation with respect to the effect of age. Retrieval from long-term semantic memory as measured by the fluency test is most resistant towards deterioration. Also, concept shifting as measured by the interference score of the CST deteriorated significantly less than other measures. This indicates that the efficiency of set-shifting and strategy-driven search in semantic memory was less compromised than that of the other functions. Furthermore, the findings clearly show that executive functioning should not be regarded as a unitary concept. This is in line with the notion that executive functioning consists of multiple dimensions, such as mental set shifting, information updating and monitoring, and inhibition of responses (Miyake et al., 2000). The present data show that executive functions are affected differently by age in the older individuals.

A second goal of the present study was to examine the effect of education and sex on cognitive functioning in a large population of older participants. Both had a substantial effect on cognitive functioning. Participants with a middle or high level of education performed on most cognitive tests significantly better than participants with a low level of education. We found no difference between middle and high levels of education. Previous research has also shown that cognitive test scores are strongly associated with level of education in a community population of people older than 65 (Evans et al., 1993; Lyketsos et al., 1999). An explanation for this education-cognition relation is that mental stimulation throughout life preserves cognitive function. It is likely that people who have had a higher level of education more often have occupations involving mental stimulation and are more likely to have more contact with people who have a greater formal education. This suggests that mental stimulation may underlie the reduced rate of deterioration in subjects with a middle or higher level of education. Interestingly, Bosma et al. (2003) demonstrated, using MAAS data of participants aged 50 years and older, that limited mental demands at work among the poorly educated participants explained about 42% of the education-cognition association. However, the exact (combination of) mechanisms by which education contributes to cognitive function are not clear and future research should focus on this aspect. The MAAS provides the opportunity to investigate this issue in the future because of its longitudinal design and the large number of variables investigated that could explain the education-cognition association.

We found no interaction between age and education, which suggests that in this sample there is no probable differential effect of educational level by age group. The finding that older adults with a low level of education appeared to perform worse on several cognitive tests than participants with a middle or high level of education, may lead to a hypothesis with respect to the nature of education as a determinant. The lack of difference between middle and high education shows that high education may be no protective factor. Conversely, low education may be a risk factor for cognitive decline. Longitudinal research on the relation between education and cognitive decline may confirm this hypothesis. In line with the present interpretation, Lyketsos et al. (1999) showed in an 11.5-year follow-up study that a greater decline on a measure of general cognitive capacity, the Mini-Mental State Examination, was associated with a lower level of education. Likewise, non-educated individuals appear to have a greater risk of suffering from dementia than educated individuals (Zhang et al., 1998). Since all these studies investigated general cognitive functioning, future studies should investigate specific cognitive domains in order to examine the longitudinal association between education and cognitive decline in more detail.

With respect to the effects of sex, the results suggest that women perform better than men on memory tasks; however, sex differences were not evident for other cognitive domains, such as speed of information processing and attention. Again, interaction effects between age and sex were not statistically significant. The first result is consistent with earlier studies, which have shown that women outperform men on memory tests (Maitland, Intrieri, Schaie, & Willis, 2000; Rabbitt, Donlan, Watson, McInnes, & Bent, 1995; Unverzagt, Hall, Torke, & Rediger, 1996). The better performance of women on memory tests may be related to higher verbal abilities because most memory tasks rely on verbal function (Herlitz, Nilsson, &

Backman, 1997). Biological mechanisms, such as atherosclerosis, could also account for these differences (Van Exel et al., 2001). Our findings that speed of information processing and set shifting were not affected by sex support earlier findings (Lowe & Reynolds, 1999). Previous research has not shown sex differences in perceptual speed in old age, whereas in younger and middle aged groups women outperform men in this domain (Maitland et al., 2000). This change in perceptual speed with increasing age may be explained by a decrease in estrogen levels in older women after the menopause. Studies have suggested that oestrogen replacement therapy can promote cognitive functions in older women (Hogervorst, Boshuisen, Riedel, Willeken, & Jolles, 1999).

In conclusion, differences in inhibitory processes, general speed, memory and learning were observed in healthy older adults (64-81 years). These age-related differences were most pronounced for functions related to inhibition. Furthermore, age-extrinsic factors, such as education and sex, had a profound influence on cognitive functioning. Therefore, the impact of educational level and sex must be taken into account when investigating an individual's cognitive functioning. Since the ability to inhibit irrelevant stimuli is crucial to various functions, it is important that interventions for older adults focus on functions that underlie inhibition of responses. This is of importance because it is at variance with the current practice, where most interventions for older adults have a strong emphasis on memory problems and memory self-efficacy. Thus, courses should be designed for healthy elderly individuals, focusing on certain executive functions. This study highlights the importance of focusing on inhibiting irrelevant stimuli. Future studies should evaluate relevant interventions in older adults, focusing on inhibiting irrelevant stimuli.

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Chapter 3

Biological and psychosocial variables as age-extrinsic factor do not contribute significantly to age-related decline in executive performance

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Abstract

Age-extrinsic factors such as high blood pressure, diabetes, and heavy alcohol consumption correlate with executive functioning in old age. However, it is not clear whether these factors are responsible for the finding that older persons perform worse on executive function tests than younger individuals on cognitive tests. This study investigated biological and psychological factors that could mediate the relationship between age and executive function. A group of 838 healthy individuals in the age range 49 and 82 years were examined in a longitudinal study of cognitive aging (Maastricht Aging Study, MAAS). Data from baseline and 3-year follow-up were included in the analyses. Linear regression models were used to compare the effect of age on the decline in cognitive performance between models with and without control for 12 biological and 9 psychosocial factors. Of the factors investigated, only a higher prevalence of hypertension and a lower level of memory self-efficacy in the older individuals contributed to their poorer executive performance. The other factors made only a marginal contribution to poorer executive function, above the factor age. Age-extrinsic factors such as those caused by illnesses or environment only marginally explained why older individuals perform worse on cognitive tests than younger people. However, the present findings underscore the notion that factors such as hypertension and memory self-efficacy should be evaluated with regard to impaired cognitive functioning in older individuals.

Introduction

Cognitive functions tend to decline from young adulthood onward. This decline is most pronounced for episodic memory, speed of information processing, and executive functioning (Bryan & Luszcz, 2000; Craik & Salthouse, 2000; Houx, Jolles, & Vreeling, 1993; Jolles, 1986). Executive functioning is important for goal-directed behaviour and is essential to many aspects of daily life, such as mental set shifting, information updating and monitoring, and inhibition of responses (Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Miyake et al., 2000). There is a paucity of data on whether there are factors, which influence this age-related decline. Yet, it is important to identify such factors because then appropriate interventions could be designed for older people with cognitive problems and thereby promote successful cognitive aging.

Previous studies have identified a number of factors that correlate with cognitive decline. Independent of age, low level of education is a strong and consistent predictor of cognitive decline (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2003; Lyketsos, Chen, & Anthony, 1999). Furthermore, high blood pressure (Launer, Masaki, Petrovitch, Foley, & Havlik, 1995), diabetes mellitus (Van Boxtel et al., 1998), poor health (McNeal et al., 2001), family history of dementia (Cervilla, Prince, Joels, Lovestone, & Mann, 2000), pesticide exposure (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2000), poor sensory functioning (Lindenberger & Baltes, 1994) and male sex (Van Exel et al., 2001) have been reported to be associated with cognitive decline. In addition, several psycho-social variables, such as depression (Comijs, Jonker, Beekman, & Deeg, 2001), anxiety (Gold & Arbuckle, 1990), low self-efficacy (Albert et al., 1995), alcohol consumption (Cervilla et al., 2000), and disengagement (Bosma et al., 2002) in otherwise healthy people appear to predict poor cognitive performance in old age, independently of age. Hence, cognitive decline is not only associated with age, but also with factors that may to some extent be amenable to modification and intervention. However, few studies have examined the contribution of such biological and psychosocial factors to the relationship between age and cognition, and executive functions in particular (Anstey, Lord, & Williams, 1997; Anstey, Stankov, & Lord, 1993). The scant research investigating this contribution is primarily concerned with memory function or intelligence (Anstey et al., 1993; Luszcz, Bryan, & Kent, 1997; West, Crook, & Barron, 1992; Zelinski, Gilewski, & Schaie, 1993). To our knowledge, no study has actually focused on executive functioning and examined the potential contribution of biological and psychosocial factors to the relation between old age and the decrease in executive functioning.

Using data from the longitudinal Maastricht Aging Study (MAAS; (Jolles, Houx, van Boxtel, & Ponds, 1995; Van Boxtel et al., 1998)), the present study selected several factors, that are known to be associated with cognitive function, and investigated their contribution to the relation between old age and declining executive functioning. More specifically, 12 biological and 9 psychosocial factors were examined for their potential role as mediators in the relation between age and executive functioning. Their effect on memory function was also investigated, to determine whether they affected executive functioning and memory in a similar fashion.

Methods

Study population

MAAS is a large-scale population study of the determinants and consequences of pathological and successful aging and of cognitive functioning in particular. MAAS consists of a large-scale cross-sectional part (n = 3,449) and an in-depth medical and neuropsychological longitudinal part among a smaller group of people (n = 1,823). The latter group was selected from the large-scale cross-sectional part. Participants were selected from a register of 15 collaborating family practices in the south of the Netherlands (Registration Network Family Practices: Metsemakers et al., 1992). These men and women, aged 24 to 81, were without medical conditions known to interfere with normal cognitive dysfunction (e.g. dementia, mental retardation, and cerebrovascular pathology). The baseline phase took place between 1993 and 1995. Details on the cross-sectional part can be found elsewhere (Jolles et al., 1995; Van Boxtel et al., 1998). Three years later (1996 – 1998), all participants aged 50 years or older and tested at baseline (n = 1,069) were again invited for a reassessment. As a result of refusal (n = 138), death (n = 50), and loss-to-follow-up (n = 43), 838 people (78 percent) were actually tested.

Measures

Age was represented as a categorical variable with the following three groups: young-old (50 through 60 years), middle-old (61 through 70 years), and old-old (71 through 81 years).

Cognitive variables

The Stroop Colour Word Test was used to evaluate executive functioning. This test involves three cards displaying 100 stimuli each. The first card contains colour words printed in black ink, which have to be read. The second card contains coloured patches, which have to be named. The third card displays colour names printed in incongruously coloured ink. Subjects were instructed to name the ink colour of the printed words. By subtracting the time needed for the last part from the mean score of the first and second parts, an interference score can be calculated (SCWT-i). This interference score is a measure of inhibition of a habitual response, which can be considered an aspect of executive function (Hammes, 1973; Houx & Jolles, 1993; Stroop, 1935).

Intentional learning and verbal memory were evaluated with the Visual Verbal Learning Test (Brand & Jolles, 1985). Fifteen monosyllabic words are presented one after another and the subject is asked to recall as many words as possible. This procedure is repeated five times. Because of ceiling effects in the last two trails, the total score of the first three trials is used as dependent variable. After 20 minutes, delayed recall is tested.

Biological factors

The following biological variables were used. 1) Sex (m,f). 2) Hypertension (no, yes), defined as a diastolic blood pressure higher than 94 mmHg or a systolic blood pressure higher than 159 mmHg, or use of antihypertensive drugs (for a detailed method see (Van Boxtel, 1997)). 3) Diabetes (no, yes), defined by the use of diabetic drugs. 4) Head trauma (no, yes), based on self-report in a structured questionnaire of such an event in combination with a loss of consciousness or posttraumatic amnesia. 5) Self-rated health, determined by asking respondents "How would you describe your health?". This item has five response categories ranging from extremely good (1) to extremely poor (5). 6) Family history of dementia (no, yes), defined by the presence of dementia in either of the parents as reported by the participants. 7) Intellectual ability, determined by using the vocabulary sub-task of the Groninger Intelligence Test (GIT; (Luteijn & van der Ploeg, 1983)). This subtask is a multiple-choice test for "crystallized" intellectual abilities. The subject is asked to indicate which of five alternate words is the exact synonym of a given word. The score ranges theoretically from 0 to 20. 8) Drug use (no, yes), defined by respondent reported use of cardiovascular drugs, drugs affecting the central nervous system (e.g. antidepressants), or other drugs with likely neurological or cognitive effects. 9) Pesticide exposure (no, yes), determined by asking whether respondents had been frequently exposed to pesticides at work or while pursuing a hobby (for details see (Bosma et al., 2000)). 10) Hearing impairment (no, yes), based on whether respondents considered they were able to hear well (using a hearing aid, if necessary (Van Boxtel et al., 2000)). 11) Vision impairment (no, yes), based on whether respondents considered they were able to see well (with appropriate spectacles, if needed (Van Boxtel, ten Tusscher, Metsemakers, Willems, & Jolles, 2001)). 12) Body mass index (BMI), computed by measuring the persons' weight (in kilograms) and height (in meter) and subsequently computing BMI=weight / $(\text{height})^2$.

Psychosocial factors

Symptoms of 1) depression and 2) anxiety were determined with the respective subscales of the Symptom-Check-List 90 (SCL-90). The SCL-90 is a widely used multidimensional checklist for psychopathological complaints (Arrindell & Ettema, 1986; Derogatis, 1977). The theoretical score for depression ranges from 0 (good) to 80 (poor). For anxiety, the theoretical score ranges from 0 (good) to 50 (poor). 3) Life-Events (no, yes) were scored by whether or not respondents reported having experienced one or more significant life-events in the past year, such as divorce or separation, change of residence, or a serious accident. 4) Level of education was measured on an 8-point scale, ranging from primary education to higher vocational training or university (De Bie, 1987). 5) Marital status was determined by asking respondents whether or not they were married. 6) Memory-self-efficacy was computed by using the Metamemory in Adulthood Questionnaire (MIA; (Dixon, Hultsch, & Hertzog, 1988; Ponds & Jolles, 1994)). The MIA is a multidimensional questionnaire in which individuals are asked to rate statements describing their memory functioning and their knowledge of general memory processes. Scores range from 3 to 15, in which lower scores indicate low perceived memory capacity. 7) Smoking (no, yes) was measured by asking whether or not respondents currently smoked. 8) Alcohol consumption (mean) was determined by asking respondents how many alcohol-containing beverages they consumed per week. 9) Disengagement (no, yes) was defined by evaluation whether or not subjects engaged in social, physical, or mental activities (Bosma et al., 2003).

Data analysis

The first analysis evaluated effects of age on cognitive performance. Linear regression analyses were used both cross-sectionally and longitudinally. In the longitudinal analyses, cognitive performance at baseline and the interval between baseline and follow-up (M= 1149.1 number of days; SD= 78.9) were included as covariates. Then the association between age and the biological and psychosocial factors was determined. Chi-square statistics were used to test for differences in categorical variables. For continuous variables, analyses of variance were performed. A third analysis evaluated the contribution of age-extrinsic factors to the age-cognitive performance association. This was done by adding the separate biological and psychosocial factors to the model in which cognitive function was regressed on age. The percent decline in strength of the age-cognitive performance association (derived from unstandardised regression coefficients) was taken as a measure of the relative contribution of the individual factors. The statistical assumptions for regression analyses were tested and appeared to be satisfied, with respect to normality of parameter distributions, and the absence of influential cases and outliers. Statistical analyses were performed using SPSS for Macintosh, version 10 (SPSS-Inc., Chicago).

Results

Compared with younger individuals, older individuals performed less well, both at baseline and during the 3-year follow-up period. At baseline, the old-old group took 22.04 seconds longer to complete the SCWT-i than the youngest group. Compared to the change in performance between baseline and follow-up in young-old people, the change in performance of the middle-old people on the SCWT-i declined 6.05 seconds more ($p=0.001$) and the score of old-old individuals decreased 13.61 seconds more ($p<0.001$). Considering the VVLT immediate recall, performance of middle-old adults declined 1.48 words more and performance of old-old participants declined 3.08 words more compared with the change in young-old individuals. Corresponding cross-sectional differences were 1.75 and 4.62.

Table 1 shows the association between age and the biological and psychosocial factors. Several biological factors were adversely related with older age. Being older was associated with a higher prevalence of hypertension ($p<0.001$), diabetes ($p<0.01$), drug use ($p<0.001$), and sensory impairment (hearing: $p=0.01$; vision $p=0.02$). Middle-old individuals reported the presence of dementia in either of their parents (25.6%) more often than did the young-old (15.2%) and the old-old people (14.1%). Several psychosocial factors were also adversely associated with older age. The proportion of married people ($p<0.001$) and the mean level of education ($p<0.001$) decreased with age. Memory self-efficacy also decreased with age ($p<0.01$). Furthermore, older adults smoked less often ($p<0.001$), consumed less alcohol ($p=0.03$) and showed less engagement in activities ($p<0.01$). For example, 20.9% of the old-old people did not engage in activities, compared with 15.2% of the young-old people and 10.7% of the middle-old individuals. Finally, older age was associated with fewer depression related symptoms ($p<0.01$), fewer anxiety related symptoms ($p=0.02$), and fewer life events in the past year ($p<0.001$).

Table 1 Relation between age and biological and psychosocial factors

	Age group Young-old	Middle-old	Old-old	Total	P-value
N	315	289	234	838	
Biological factors					
Sex (%) men	53.7	53.3	48.3	52.0	
Hypertension (%)	34.3	57.1	68.8	51.8	**
Diabetes (%)	2.3	5.6	8.5	5.1	*
Head trauma (%)	2.9	2.8	3.8	3.1	
Self-rated health (mean)	3.8	3.6	3.7	3.7	
Family history dementia (%)	15.2	25.6	14.1	18.5	**
Intellectual ability (mean)	13.7	13.5	13.5	13.6	
Drug use (%)	38.4	51.2	61.5	49.3	**
Pesticide exposure (%)	1.7	2.9	1.9	2.1	
Hearing impairment (%)	10.2	11.5	18.5	12.9	*
Vision impairment (%)	1.3	4.5	5.6	3.6	*
BMI (mean)	27.6	27.8	27.6	27.6	
Psycho-social factors					
Depression (mean)	21.5	20.9	19.7	20.8	*
Anxiety (mean)	13.1	12.7	12.1	12.7	*
Life-events (%)	66.3	59.5	46.2	58.4	**
Level of education (mean)	3.3	2.8	2.8	3.0	**
Marital status (% not married)	11.5	16.3	37.6	20.4	**
Memory self-efficacy (mean)	9.5	9.2	9.0	9.3	*
Smoking (%)	31.5	23.0	14.0	23.7	**
Alcohol consumption (mean)	6.7	5.2	4.9	5.7	*
Disengagement (%)	15.2	10.7	20.9	15.3	*

Reported are means of the factors by age group and the significance of group differences (ANOVA, or Chi2, where appropriate).
*$p \leq 0.05$; **$p \leq 0.01$

Table 2 shows the contribution of the biological and psychosocial factors to the age-related change in the SCWT-i score, both cross-sectionally and longitudinally. In the cross-sectional analyses, the contribution of the factors to the association between change in SCWT-i performance and age varied between 0% and 24%. For example, the basic age regression model revealed that the performance on SCWT-i of the old-old individuals was 22.04 seconds slower than that of the young-old individuals. After controlling for hypertension status, the regression coefficient for the old-old people decreased to 21.5, indicating that they took 21.5

seconds longer to perform the test than young-old individuals. The higher prevalence of hypertension in the old-old group thus partially explained (i.e. 2% (22.0-21.5)/22.0) the basic age effect. Overall, the contribution of hypertension, diabetes, intellectual ability, hearing impairment, educational level, marital status and memory self-efficacy was most pronounced.

Table 2. Contributions of the biological and psychosocial factors to the association between age and executive functioning.

	SCWT-i			
	Cross-sectional		Longitudinal	
	Middle-old	Old-old	Middle-old	Old-old
Basic age model	7.12	22.04	6.05	13.61
Biological factors				
Sex (men)	7.13 (-)	22.11 (-)	6.09 (-)	13.84 (-)
Hypertension	6.76 (5)	21.49 (2)	5.36 (11)	12.62 (7)
Diabetes	6.82 (4)	21.39 (3)	5.96 (1)	13.46 (1)
Head trauma	7.08 (1)	22.00 (0)	6.08 (-)	13.65 (-)
Self-rated health	6.83 (4)	21.87 (1)	5.97 (1)	13.60 (0)
Family history of dementia	6.81 (4)	22.06 (-)	5.76 (5)	13.70 (-)
Intellectual ability	6.72 (6)	21.53 (2)	6.07 (-)	13.72 (-)
Drug use	7.11 (0)	22.01 (0)	6.08 (-)	13.66 (-)
Pesticide exposure	7.02 (1)	22.02 (0)	6.01 (1)	13.65 (-)
Hearing impairment	6.75 (5)	21.72 (1)	6.18 (-)	12.94 (5)
Vision impairment	7.10 (-)	22.02 (0)	5.83 (4)	13.37 (2)
BMI	7.04 (1)	22.05 (-)	6.05 (0)	13.62 (-)
Psycho-social factors				
Depression	6.62 (7)	23.04 (-)	6.13 (-)	11.63 (15)
Anxiety	6.49 (9)	22.12 (-)	6.16 (-)	11.81 (13)
Life-events	7.10 (0)	21.97 (0)	5.97 (1)	13.36 (2)
Level of education	5.44 (24)	20.25 (8)	5.95 (2)	13.58 (0)
Marital status (not married)	6.78 (5)	20.60 (7)	6.15 (-)	14.47 (-)
Memory self efficacy	6.06 (15)	21.42 (3)	5.57 (8)	12.33 (9)
Smoking	7.29 (-)	22.98 (-)	6.07 (-)	13.45 (1)
Alcohol consumption	6.92 (3)	21.72 (1)	6.23 (-)	13.84 (-)
Disengagement	7.42 (-)	21.59 (2)	6.14 (-)	13.58 (0)

All coefficients were significant at the $p<0.01$ level.
Contribution of each factor (expressed as a percentage) is displayed between brackets. No value (i.e. "-") was entered in case of no contribution. The contribution was calculated by subtracting the coefficient of age in the basic age model from the coefficient of age in the model with the additional factor. Subsequently, this subtraction was divided by the coefficient of age in the basic age model and multiplied by 100.

In the longitudinal analyses, hypertension (7-11%) and memory self-efficacy (8-9%) contributed the most to the age-related cognitive decline. The change in SCWT-I performance was 13.61 seconds worse for old-old people than in the young-old people. Again, after controlling for hypertension status, the change in SCWT-I performance of the old-old group was 12.6 seconds worse than that of the change in young-old people. Hypertension thus accounted for 7% of the association between change in SCWT-I performance and age. Interestingly, the contribution of education was more pronounced cross-sectionally than longitudinally, which may be due to a cohort effect. In both the cross-sectional and longitudinal analyses, the contribution of depression and anxiety was moderate (7-15%). However, this contribution was not relevant because the old-old people reported fewer depressive and anxiety complaints (see Table 1). Overall, the variables that did have some effect were hypertension and memory self-efficacy. Other factors did not substantially contribute to age-related change in SCWT-I. On average less than 10% of the age effect could be explained by mediating factors.

Inclusion of all biological factors in the longitudinal basic age regression model reduced the association between age and change in SCWT-i performance from 13.6 seconds to 12.4 seconds (9% reduction). Inclusion of all psychosocial factors in the main model decreased the association from 13.6 seconds to 11.1 seconds (18% reduction). If hypertension and memory self-efficacy were entered simultaneously, the unstandardised coefficient decreased from 13.6 seconds to 11.3 seconds (17% reduction). Similar results were obtained in analyses with age as a continuous variable. When the analyses were repeated with other measures of executive functioning (the Fluency task (Lezak, 1995) or the interference score of the Concept shifting task (Vink & Jolles, 1985)), or measures of general speed of information processing (mean score of the first and second card of the SCWT), the results were essentially the same (data not shown).

Biological and psychosocial factors contributed on average less than 9% to the association between VVLT immediate recall performance and age in the cross-sectional and longitudinal analyses (see Table 3). The factors that marginally predicted age-associated cognitive change were hypertension (4-9%), level of education (3-15%) and memory self-efficacy (3-9%).

Table 3. Contributions of the biological and psychosocial factors to the association between age and memory functioning

	Cross-sectional		Longitudinal	
	Middle-old	Old-old	Middle-old	Old-old
Basic age model	-1.75	-4.62	-1.48	-3.08
Biological factors				
Sex (men)	-1.76 (-)	-4.72 (-)	-1.50 (-)	-3.13 (-)
Hypertension	-1.64 (6)	-4.44 (4)	-1.34 (9)	-2.86 (7)
Diabetes	-1.67 (5)	-4.47 (3)	-1.48 (0)	-3.07 (0)
Head trauma	-1.75 (-)	-4.61 (0)	-1.47 (1)	-3.06 (1)
Self-rated health	-1.65 (6)	-4.56 (1)	-1.46 (1)	-3.08 (0)
Family history of dementia	-1.78 (-)	-4.61 (0)	-1.46 (1)	-3.08 (0)
Intellectual ability	-1.69 (3)	-4.55 (2)	-1.52 (-)	-3.22 (-)
Drug use	-1.71 (2)	-4.55 (2)	-1.46 (1)	-3.03 (2)
Pesticide exposure	-1.73 (1)	-4.62 (0)	-1.48 (0)	-3.08 (0)
Hearing impairment	-1.70 (3)	-4.63 (-)	-1.51 (-)	-3.01 (2)
Vision impairment	-1.78 (-)	-4.66 (-)	-1.42 (4)	-2.96 (4)
BMI	-1.76 (-)	-4.63 (-)	-1.48 (0)	-3.07 (0)
Psycho-social factors				
Depression	-1.83 (-)	-4.52 (2)	-1.46 (1)	-3.18 (0)
Anxiety	-1.83 (-)	-4.54 (2)	-1.44 (3)	-3.13 (0)
Life-events	-1.77 (-)	-4.69 (-)	-1.50 (0)	-3.11 (0)
Level of education	-1.49 (15)	-4.35 (-)	-1.35 (9)	-2.99 (3)
Marital status (not married)	-1.78 (-)	-4.69 (-)	-1.46 (2)	-3.01 (2)
Memory self efficacy	-1.60 (9)	-4.35 (6)	-1.43 (3)	-2.96 (4)
Smoking	-1.76 (-)	-4.62 (-)	-1.44 (3)	-2.99 (3)
Alcohol consumption	-1.81 (-)	-4.70 (-)	-1.43 (4)	-3.02 (2)
Disengagement	-1.81 (-)	-4.55 (2)	-1.55 (0)	-3.12 (0)

All coefficients were significant at the $p<0.01$ level.

Contribution of each factor (expressed as a percentages) is displayed between brackets. No value (i.e. "-") was entered in case of no contribution. The contribution was calculated by subtracting the coefficient of age in the basic age model from the coefficient of age in the model with the additional factor. Subsequently, this subtraction was divided by the coefficient of age in the basic age model and multiplied by 100.

Discussion

The purpose of the present study was to identify factors that potentially explain why older individuals perform worse on tests of executive functioning than younger individuals. The findings indicate that most factors, such as diabetes, self-rated poor health, drug use, low intellectual ability, depression, and low level of education, contributed very little to the confirmed worse cognitive performance of older adults. On average, potential mediating factors accounted for less than 10% of the association between old age and diminished executive functioning. Some factors contributed marginally to age-related changes in executive functioning. Older individuals more often have hypertension and low memory self-efficacy, and these two variables partially explained why they perform worse on tests of executive function. Therefore, interventions focusing on these factors may have some potential for improving executive functioning in older people.

Studies examining age-related differences in memory tasks performance have also revealed a minor contribution of biological and psychosocial factors to age-related cognitive change (Anstey et al., 1993; Luszcz et al., 1997; West et al., 1992; Zelinski et al., 1993). For example, West and colleagues (1992) investigated in healthy adults aged 18 to 90 years whether several variables, such as education, depression, and sex, mediated the effect of age on the performance of memory tests. They concluded that age remains the best overall predictor of memory performance. Our findings for memory corroborated the above-mentioned studies in that the contribution of the age-extrinsic factors to age-related memory change appeared to be minor. A higher prevalence of hypertension and low memory self-efficacy in the old-old individuals partially explained the poorer memory function of this group. Hence, the relatively low contributions of age-extrinsic factors to the age - cognition relation are evident on both cognitive domains (memory or executive function).

According to Busse (1969), a distinction can be made between primary aging and secondary aging. Primary aging refers to changes intrinsic to the aging process. Secondary aging is defined as changes caused by trauma and disease that are correlated with age but which may be reversible or preventable. With this in mind, the results of this study suggest that variables of secondary aging have only a minor influence on executive functioning and that age per se may be the best predictor of cognitive decline. This raises the question what primary aging actually is and how it should be measured. Reduced brain efficiency of older persons can be the result of physiological changes in the blood supply to the brain and/or to decreased efficiency of the transportation of substances which are essential to brain functioning. These physiological changes eventually give rise to a loss of dendritic extensions, to a decrease in the number of synapses, and to a reduction in cellular mechanisms that support the synthesis and transmission of various neurotransmitters (Tisserand et al., 2002; West, 1996). Further research should be devoted to the evaluation of the primary mechanisms involved.

A strong point of this study was the availability of a large number of healthy middle-aged to very old subjects and data on a substantial number of biological and psychosocial factors. However, some relevant factors were not included in this study, for example Apolipoprotein-E genotype (Anstey & Christensen, 2000; McNeal et al., 2001; Swan & Carmelli, 2002). Previous research has shown that ApoE4 is associated with cognitive change and early onset of Alzheimer's disease. Another methodological consideration is that some factors, such as diabetes and sensory impairments, were measured by self-report, which may not adequately reflect these impairments. Lastly, the 3-year follow-up period of this study is relatively short, and longer follow-up intervals may be needed to confirm or refute the present findings.

In conclusion, our findings suggest that biological and psychosocial factors only marginally explain why executive functioning is worse in older people than in younger people. This may provide support for the hypothesis of primary aging, which states that changes intrinsic to the aging process are responsible for the decline in cognitive functioning, notably executive functioning and memory.

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Chapter 4

Relation between health status and cognitive functioning: 6-year follow-up of the Maastricht Aging Study

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Abstract

The aim of this study was to determine whether health status (i.e. physical, social and psychological functioning) can predict 6-year cognitive decline in older adults and to explore the relative contribution of the components of health status to long-term changes in cognitive performance. A group of 669 participants aged 60 to 81 was recruited from a longitudinal study (Maastricht Aging Study). A poor health status was related to poor cognitive functioning and to cognitive decline 6 years later. Physical, social, and psychological functioning were related to several measures of cognitive functioning at baseline. Psychological functioning at baseline was related to memory functioning 6 years later. In conclusion, poor psychological functioning, rather than poor physical and poor social functioning may have the strongest implications for long term cognitive functioning in older men and women.

Introduction

In view of the substantial heterogeneity and range in functioning observed in community based populations, Rowe et al. (1987) proposed that normally aging people should be subdivided into a group that functions at a normal level and a group that functions at an optimal level. They used the term 'successful aging' to denote the latter group. In order to increase the chances of a long, active and independent life, more knowledge about factors that are associated with optimal functioning in old age is needed. In order to reveal such factors, it is worthwhile to focus on people that are functioning at high levels on physical, psychological and social aspects. These three aspects determine the health status of an individual according to the long-standing definition by the World Health Organization (1948). Several studies have focused on factors that are related to high functioning within different functional domains. For example, older people who function at a high level are more likely to be highly educated and to have a high income (Fisher, 1995; Jorm et al., 1998; Vaillant & Mukamal, 2001). Furthermore, a high level of general functioning is suggested to be positively associated with high cognitive functioning or is even seen as an aspect of a high level of general functioning (Berkman et al., 1993; Rowe & Kahn, 1997). Despite these suggestions few studies have examined in depth the relationship between general high functioning and cognitive performance.

In old age, many cognitive functions decline, such as explicit memory, executive functions, and speed of information processing (Bryan & Luszcz, 2000; Houx, Jolles, & Vreeling, 1993; Jolles, Verhey, Riedel, & Houx, 1995). Typically, differences in cognitive performances between individuals become more pronounced as people age (Bryan & Luszcz, 2000; Houx & Jolles, 1993; Jolles, Houx, Vreeling, & Verhey, 1993; Salthouse, 1998). While older people may function within the range of performance of young individuals on several cognitive domains, they more often perform on a lower level than their younger counterparts. In order to determine the specific characteristics of individuals with a high level of general functioning, it is of scientific and applied interest to know whether such individuals also perform better on cognitive tests.

Previous studies have identified associations between one of the three components of health status (i.e. physical, social and psychological functioning) and cognitive functioning (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2003; Christensen et al., 1996; Jorm, 2000; McNeal et al., 2001). For example, complaints about mood, related to depression, have been associated with a decline in speed of information processing over a 3-year period in healthy older adults (Comijs, Jonker, Beekman, & Deeg, 2001). An explanation for this finding is that people who are anxious or depressed may be less motivated and have more worries and other intrusive thoughts that compete for resources in working memory, resulting in a poor performance on cognitive tasks (Eysenck, 1992). Another explanation is that depression or anxiety initiates or accelerates neurodegenerative processes (Yaffe et al., 1999) or is a reaction to a perceived deterioration in cognitive function (Paterniti, Verdier-Taillefer, Dufouil, & Alperovitch, 2002; Stewart, 2004; Wilson, Mendes De Leon, Bennett, Bienias, & Evans, 2004).

Psychosocial factors, such as lifestyle and emotional support, also appeared to have a profound influence on age-related cognitive decline in middle- and old-aged, non-demented people (Bosma et al., 2003; Seeman, Lusignolo, Albert, & Berkman, 2001). For example, Seeman et al. (2001) demonstrated in 1189 adults aged 70-79 that more emotional support was associated with a better score on tasks assessing multiple cognitive domains, such as language, abstraction, and memory. People who take part in challenging activities keep using cognitive strategies and mechanisms that promote stability or even enhance cognitive functioning (Hultsch, Hammer, & Small, 1993, Hill, 1995). It is therefore not expected that social functioning would be associated with a certain aspect of cognitive functioning.

Poor physical function, as indexed by self-rated health (Earles, Connor, Smith, & Park, 1997; Hultsch et al., 1993; Perlmutter & Nyquist, 1990) (Van Boxtel, Langerak, Houx, & Jolles, 1996), was found to be related to poor performance on neuropsychological tests in a healthy population. In a study of 488 community dwelling adults aged 70-79, Tabbarah et al. (2002) showed that decline on a broad range of cognitive measures was associated with declines in physical tasks, such as standing a single leg or walking at a normal pace (Tabbarah, Crimmins, & Seeman, 2002). It was suggested that physical functioning may influence basic biological mechanisms, such as limb strength and aerobic capacity and as a consequence may affect in particular basic cognitive processes, such as speeded task performance (Hultsch et al., 1993).

A limitation of these studies is that they highlighted only one aspect of physical, psychological, or social functioning. Whether a high level of functioning on a combination of these three domains is related to better cognitive functioning in older individuals has not been investigated, neither has the relative importance of these three domains been explored with respect to cognitive functioning. We sought to address this by investigating whether health status (a combination of physical, psychological and social functioning) is related to cognitive functioning and cognitive change over a 6-year period in a large population sample aged 60 years and older derived from the Maastricht Aging Study. We also studied whether the three components have a similar independent predictive power regarding cognitive performance.

Methods

Participants

The data used in the present study were derived from the Maastricht Aging Study, a longitudinal study examining determinants of normal cognitive aging. Participants were recruited from the Registration Network Family Practices (RNH), a sample frame for research in primary care (Metsemakers, Höppener, Knottnerus, Kocken, & Limonard, 1992). These men and women, aged 24 to 81 at the moment of inclusion, were without medical conditions known to interfere with normal cognitive function (e.g. dementia, mental retardation, or cerebrovascular pathology). The study population was stratified for age group, sex, and general ability. In the baseline period between 1993 and 1995, 1,823 people underwent a cognitive and physical examination, (Jolles, Houx, van Boxtel, & Ponds, 1995). Six years after the baseline measurements, all participants were invited for a reassessment of neuropsychological function. Due to refusal (n=275), death (n=116), loss to follow-up (n=37), and other reasons (n=19), in total 1,376 participants were actually tested (74%). For the present study, only data for participants aged 60 years or older were used (n=669 (37% of the total study population); 335 men, 334 women), because health and cognitive problems occur more often, and are more severe, in this age group. Data for participants with clinically verified major depression or dementia at 6-year follow-up were excluded from further analyses (n=12, 1.8%). The local medical ethics committee approved the study and all participants gave their informed consent.

Health status

The definition of health status was based on three components: physical functioning, social functioning and psychological functioning (World Health Organization, 1948). Physical functioning was measured in terms of perceived health and problems with instrumental activities of daily living (IADL). Perceived health was determined by asking respondents "how would you describe your health?", with answers ranging from extremely good (1) to extremely poor (5). Problems with IADL were measured by asking the respondents whether they needed help with shopping, housekeeping, personal hygiene, dressing, and preparing meals, with scores ranging from 0 (no help) to 10 (maximum help). Social functioning was defined by the number of hours per week a person was engaged in social activities at a club. Psychological functioning was determined by the subscales depression and anxiety of the Symptom-Check-List 90 (SCL-90). The SCL-90 is a widely used multidimensional checklist for psychopathological complaints (Arrindell & Ettema, 1986; Derogatis, 1977); scores range from 0 (good) to 80 (poor) for depression, and from 0 (good) to 50 (poor) for anxiety.

In order to obtain a single score for health status, the five variables were first standardized (Z-scores). If two variables (e.g. self-rated health and IADL) defined one component (e.g. physical functioning), these were averaged in order to obtain equal weights for the three components physical, social, and psychological functioning. A single score for health status was calculated by adding the three components.

Cognitive variables

A broad range of cognitive tests was administered to assess perceptual speed, speed of information processing, cognitive flexibility, memory, and verbal fluency. These tests have been shown to be sensitive to age-related changes and subtle changes in health (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2000; Salthouse, 1992; Van Boxtel et al., 1998; Van Boxtel et al., 2000).

The Stroop Colour-Word Test (SCWT) is a measure of selective attention and speed of information processing. This test involves three cards displaying 100 stimuli each (Houx & Jolles, 1993; Stroop, 1935). The first card contains colour words printed in black ink, which have to be read aloud. The second card contains coloured patches, which have to be named. The last card displays colour names printed in incongruously coloured ink. Participants were instructed to name the ink colour of the printed words. By subtracting the time needed for the last part from the mean score of the first and second parts (SCWT-12), an interference score can be calculated (SCWT-i). This interference score is a measure of inhibition of a habitual response, which can be considered an aspect of executive function.

The Concept Shifting Task (CST) is a modified version of the Trial Making Test (Vink & Jolles, 1985) and is used as an instrument to measure simple cognitive speed and cognitive flexibility. It consists of three parts. On each test sheet, 16 small circles are grouped in a larger circle. The smaller circles contain numbers, letters or both, appearing in a fixed random order. Participants were requested to cross out the items in the right order. In the last part, participants had to alternate between numbers (1-8) and letters (A-H). The scores correspond to the time needed to complete each trial. The difference between the last part (CST-c) and the mean score of the first and second parts (CST-ab) is considered to reflect the additional time needed to shift between both sets of stimuli (CST-i).

The Letter-Digit Substitution Test (LDST) measures general information processing speed. This test is a modified version of the Symbol Digit Modalities Test (Lezak, 1995; Smith, 1968). A code is presented at the top of a page, where a digit is linked to a letter. The participants had to fill in blank squares that correspond to the correct code. The dependent variable is the number of letters filled in correctly in 90 seconds.

Intentional learning and verbal memory functioning were measured using the Visual Verbal Learning Test (VVLT; Brand & Jolles, 1985). Fifteen monosyllabic words are presented one after another and subjects are asked to recall as many words as possible. This procedure is repeated five times. The first trial can be seen as a measure of short-term memory. Because of potential ceiling effects in the last two trails, the total score of the first three trails is used as dependent variable. After 20 minutes, delayed recall is tested.

In the Verbal Fluency Test (Lezak, 1995) participants are asked to produce as many words as possible in a given category (animals), within 60 seconds. The variables of interest are the number of correctly named animals. The score can be seen as a measure for adequate, strategy-driven retrieval of information from semantic memory.

Cognitive compound scores

In order to reduce the number of tests while improving the robustness of the underlying cognitive construct (Lezak, 1995), we calculated cognitive compound scores. To this end, raw scores of both baseline assessment and follow-up assessment were transformed to Z-scores in the total group of participants that was selected in this study. Both observations for each individual were pooled for Z-score computation, in order to obtain both inter-individual differences and intra-individual change over time. The memory compound score was based on the immediate and delayed recall of the VVLT. The speed compound was derived from the first and second subtask of the SCWT and CST. The executive functioning compound score was calculated by averaging the interference scores of the SCWT and CST. The sign of the speed and executive compound scores was inverted to make them reflect above average performance when positive and below average performance when negative (Van Boxtel et al., 1998).

Other measures

Age, sex, and level of education were considered potential confounders. Level of education was indexed on an 8-point ordinal scale: 1=primary education, 2=lower vocational education, 3=intermediate general secondary education, 4= intermediate vocational education, 5=higher general secondary education/ university preparatory education, 6=higher vocational preparatory education, 7=higher professional education, 8=university education (De Bie, 1987).

Data analysis

First, the cross-sectional relation between health status and the cognitive compound scores was analysed by linear regression analysis adjusted for age, sex, and educational level. Linear regression analysis was also used, to analyse the longitudinal association between health status and cognitive decline over the 6-year follow-up period. These associations were adjusted for age, sex, educational level, duration of follow-up interval (mean: 2259 days, SD: 63), and cognitive performance at baseline. After calculation of correlation coefficients between the three health components (i.e. physical, social, and psychological functioning), the relative importance of each specific continuous component was examined by introducing the three components simultaneously in the cross-sectional and longitudinal regression models. Analyses were corrected for the above-mentioned confounders. Analyses were performed using SPSS for Macintosh, version 10 (SPSS-Inc., Chicago).

Results

After adjustment for age, sex, and educational level, regression analysis showed that poor health status at baseline was related to lower speed and executive functioning compound scores and to worse performance on the LDST. Longitudinal analysis revealed that health status was related to cognitive decline over the 6-year follow-up interval (Table 1). During follow-up, the lower functioning participants had a stronger decrease in memory and LDST performance than the high functioning participants. No association was observed between health status at baseline on the one hand and a change in performance on the speed, executive functioning compound score or the fluency test on the other.

Table 1. Association (Standardized Regression Coefficients) between Health Status and Cognitive Functioning

	Health status			
	Cross-sectional		Longitudinal	
	Beta	p-value	Beta	p-value
Memory	-0.07	0.08	-0.08	0.03
Speed	-0.17	0.00	0.01	0.77
Executive functioning	-0.15	0.00	-0.06	0.14
LDST	-0.15	0.00	-0.09	0.00
Fluency	-0.07	0.08	-0.07	0.08

Note: Cross-sectional analyses were based on baseline data and were adjusted for age, educational level, and sex. Longitudinal analyses were adjusted for age, sex, educational level, length of follow-up interval and cognitive functioning at baseline; *LDST=Letter-Digit Substitution Test*.

The correlation between physical functioning on the one hand and social functioning and psychological functioning on the other hand was significant ($r=0.12$, $p<0.01$ and $r=0.37$, $p<0.001$, respectively). The correlation between psychological functioning and social functioning was not significant ($r=-0.02$, $p=0.67$). Table 2 summarizes standardized regression coefficients of the three components of health status (i.e. physical, social, and psychological functioning) for each cognitive measure separately. Physical functioning was significantly correlated with the speed compound score: higher physical functioning was associated with better performance on speed tasks. Social functioning was related to better performance on the speed, executive functioning score and the LDST. The psychological functioning component was related to the executive compound score: higher psychological functioning was associated with better performance. The longitudinal analyses revealed a different pattern. Social and physical functioning did not predict the cognitive functioning 6 years later. Psychological functioning was related to the memory compound score, and in LDST performance 6 years later.

Table 2
Standardized Regression Coefficients of Standardized Health Status Components for Each Cognitive Measure

	Physical Functioning	Social Functioning	Psychological Functioning
Cross-sectional			
Memory	-0.07	-0.04	0.01
Speed	-0.11**	-0.09*	0.06
Executive functioning	-0.02	-0.08*	-0.13**
LDST	-0.06	-0.11**	-0.05
Fluency	-0.06	-0.02	-0.02
Longitudinal			
Memory	-0.02	-0.01	-0.01
Speed	-0.03	0.04	0.04
Executive functioning	-0.06	0.01	0.01
LDST	-0.05	-0.03	-0.03
Fluency	-0.05	-0.03	-0.03

Note: Cross-sectional analyses were adjusted for age, sex and educational level. In longitudinal analyses age, sex, educational level, period to follow-up and baseline cognitive performance were included as covariates (components simultaneously controlled).
LDST=Letter-Digit Substitution Test.
*$p<0.05$; ** $p<0.01$

Discussion

The main aim of this study was to examine the relationship between components of health status and cognitive functioning. Results indicate that older individuals with a higher level of physical, social, and/or psychological functioning, perform better on cognitive tasks, including those related to memory, executive functions, and speed of information processing. In addition, longitudinal data revealed that participants with a higher baseline level of health status defined as a combination of physical, psychological, and social functioning had a better cognitive functioning 6 years later than did participants with a lower level of health status at baseline. The cognitive performance, and in particular the memory functioning, of people with a higher level of health status decreased less than that of people with a lower health status.

The most important component of health status in terms of its association with cognition 6 years later was psychological functioning. As expected, a high level of physical functioning was associated with a better speed compound score only. While psychological functioning at baseline predicted memory performance 6 years later, it was not correlated with memory functioning at baseline. The participants of this study were healthy older adults who may experience health problems in the future, problems, which may affect their cognitive function. It is possible that symptoms related to mood, such as depression or anxiety, may initiate neurodegenerative processes that lead to impairment of cognitive functioning.

The finding that social functioning was not related to cognitive functioning 6 years later, whereas previous longitudinal studies did find such an association (Hultsch, Hertzog, Small, & Dixon, 1999; Seeman et al., 2001), may be due to the way we operationalized social functioning. We used the number of hours a week people engaged in social activities at a club as a measure of social functioning. This variable reflects the tendency to engage in outgoing social activities and enables to explore the frequency of engaging in social activities, but it may be limited in robustness to capture the broad concept of social functioning. Thus our findings on the relation between the social component and cognitive functioning should be interpreted with caution. Additional analyses in order to examine the reverse relationship, i.e. the effect of cognitive function on changes in social functioning, indicated that good baseline cognitive functioning increased the social activity level (not tabulated).

In the present study, low correlations were found between physical, social and psychological functioning, indicating that it is unlikely that many people enjoy a high level of functioning in all three aspects of health status. In the future, cluster analyses can be used to formally test whether this is the case. Furthermore, further analyses should also address the extent to which cognitive functioning is the cause or the result of health status and whether changes in cognitive functioning follow the same time course as changes in health status. For example, in this cohort social functioning, as a component of health status, appeared to be the result of good cognitive performance rather than the reverse. However, psychological functioning also had predictive power regarding cognitive functioning.

Related, more in depth research may shed further light on the concept of successful aging as defined by several authors (e.g. Rowe & Kahn, 1987), its measurements, and the extent to which cognitive functioning is involved. A complicating factor in the research on successful aging performed up till now remains the absence of uniform criteria, which hampers the comparability of studies focusing on this topic. Previous studies have used a variety of definitions, based on different combinations of the health components described above. For example, some studies have defined successful aging solely in terms of adequate physical functioning (Guralnik & Kaplan, 1989; Strawbridge, Cohen, Shema, & Kaplan, 1996), while others have focused primarily on both physical and psychological functioning (Berkman et al., 1993; Roos & Havens, 1991). Still other researchers have included a combination of physical measures and cognitive aspects in their definition of high functioning (Berkman et al., 1993; Rowe & Kahn, 1997). However, none of these studies has critically addressed the relevance of cognition to their definition. The results of the present study suggest that the role of optimal cognitive functioning in successful aging may be partly dependent on which component of successful aging/health status is being investigated.

Several methodological issues need to be considered. First, the people who participated in this study were healthy community dwelling adults and thus health selection bias may have occurred. Thus the results of this study may not be applicable to people with mild cognitive impairment or neurodegenerative diseases, such as dementia. Aspects of health status were measured by self-report. A disadvantage of self-report data is that informants may forget information, which will decrease reliability. However, the ecological validity of self-reported information is generally considered being high. Interestingly, recent literature suggests that high functioning or successful aging should be measured in a qualitative way, to compare definitions of successful aging developed by researchers with those defined by aging individuals. This would make it possible to formulate a more client-centered definition of successful aging (Phelan & Larson, 2002; Von Faber et al., 2001).

In conclusion, a high health status, defined as good physical, social, and psychological functioning predicts cognitive decline in older adults. Comparison of these components revealed that poor psychological functioning is the best predictor of cognitive decline. The important role of symptoms related to mood, energetic functions, mild dysthymia, or anxiety complaints should be investigated in the future.

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Chapter 5

Influence of cognitive functioning on functional status in an older population: 3- and 6-year follow-up of the Maastricht Aging Study

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Abstract

To date, it remains unclear to what extent cognitive competence is related to a change in general functional status in older adults. The present study evaluates both the cross-sectional and the longitudinal relation between cognitive functioning and functional status. Sensorimotor speed, memory, and executive functioning were assessed in a large population of healthy adults aged 60 years and older (n=485) who participated in the Maastricht Aging Study. Data from the baseline (1993-1995), 3-year follow-up, and 6-year follow-up were used. Functional status was measured using the SF-36, which was coded into a physical and a mental component summary measure. After adjustment for age, sex, and educational level, a high level of cognitive functioning appeared to be associated with better functional status in the cross-sectional analysis. Longitudinal analyses demonstrated, that cognitive functioning was not a predictor of functional status 3 or 6 years later. Thus while cognitive functioning is useful clinically for predicting the short-term functional status of an older person, it is not useful for predicting that person's long-term (> 3 years) functional status and thus the period of validity of the results of these tests in answering such questions is limited.

Introduction

In Western society, with its rapidly growing population of older individuals, it is important to identify functional limitations that could limit the autonomy of older adults. Neuropsychologists are increasingly being asked to evaluate person's capabilities and limitations, and in many cases to answer questions concerning the functional status and consequences of cognitive limitations on daily life, such as a person's ability to take care of himself/herself and to manage his/her finances (Barth et al., 2003; Lezak, 1995). But how strong is the evidence that cognitive competence is actually associated with general functional status or autonomy? With a view to the increasing number of older adults and health care consumption, it is worthwhile to investigate in healthy old adults whether cognitive functions are associated with functional status.

To date, several largely cross-sectional studies have provided some evidence that impaired cognitive functioning is associated with poor functional status (Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Cahn-Weiner, Boyle, & Malloy, 2002; Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000; Carlson et al., 1999; Gill, Williams, Richardson, Berkman, & Tinetti, 1997; Greiner, Snowdon, & Schmitt, 1996; Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998; Padoani et al., 1998; Richardson, Nadler, & Malloy, 1995), particularly in cognitively impaired people. For example, Greiner et al. (1996) showed that adults older than 75 years with a Mini Mental State Examination (MMSE) score <27 had twice the risk of losing their independence in one or more activities of daily living, such as bathing, dressing, and eating independently, after 1 year, compared to those with a higher cognitive performance. Bell-McGinty et al. (2002) reported similar findings. In their study of 50 older people, most of whom had impaired cognitive functioning Bell-McGinty and colleagues showed that performance on tests of executive functioning was associated with the individual dependence in activities of daily living, such as management of personal finance. Such studies have tended to focus on older adults with mild cognitive impairment or neurodegenerative diseases (Bell-McGinty et al., 2002; Richardson et al., 1995) or used a rather broad cognitive measure (i.e. MMSE score (Folstein, Folstein, & McHugh, 1975)) (Gill et al., 1997; Grigsby et al., 1998; Padoani et al., 1998).

With respect to the measurement of cognitive performance in healthy elderly, there is ample evidence that cognitive rating scales such as the MMSE are too insensitive to evaluate performance on specific cognitive domains, and thus cannot be used to determine whether specific cognitive domains are affected (MacKenzie, Copp, Shaw, & Goodwin, 1996). Adequate performance in the domain of executive functions seems particularly relevant in this respect, because it enables a person to state and perform goals, deal with novelty, solve problems, adapt to unexpected circumstances, and perform multiple tasks (Lezak, 1995). If a person's executive functioning is inadequate, he/she will probably experience difficulties in performing multiple activities in daily life, such as managing a home, finances, or even taking medication, difficulties which adversely affect the functional status of that person.

Our aim was to investigate the cross-sectional and longitudinal relation between important cognitive domains (i.e. memory performance, executive functioning, and speed of information processing) and functional status in a large healthy sample of adults aged 60 years and older. We expected that executive functioning would be most strongly associated with functional status.

Methods

Participants

The data used in the present study were derived from the Maastricht Aging Study, a longitudinal study examining determinants and consequences of differences in normal cognitive aging. Participants were recruited from a collaborating network of family practices (Metsemakers, Höppener, Knottnerus, Kocken, & Limonard, 1992). All participants were between 24 and 81 years of age, and were at the moment of inclusion without medical conditions known to interfere with normal cognitive function (e.g. dementia, mental retardation, and cerebrovascular pathology). The study population was stratified for age group, sex, and general ability. In the baseline period between 1993 and 1995, 1,823 people underwent a cognitive and physical examination, (Jolles, Houx, van Boxtel, & Ponds, 1995). About 3 years later (1996-1998), all people who were 50 years or older (n=1,069) were invited to participate in a re-assessment of their neuropsychological functioning. Because of refusal (n=138), death (n=50), loss to follow-up (n=43), 838 persons (78%) were actually tested. Six years after the baseline measurements, all participants were again invited for a neuropsychological examination. Due to refusal (n=275), death (n=116), loss to follow-up (n=37), or other reasons (n=19), in total 1,376 participants were actually tested (74%). For the present study, only data for participants aged 60 years or older were used. Data for participants with clinically verified major depression or dementia at 3- or 6-year follow-up were excluded from further analyses (n=12, 1.8%). The local medical ethics committee approved the MAAS-study and all participants gave their informed consent.

Cognitive variables

Many studies have shown that the first cognitive changes associated with aging are observed in the domains of memory functioning, executive functioning, and speed of information processing (e.g. Jolles, 1986; Salthouse, 1992)). In addition, tests that draw on these domains have been shown to be sensitive to subtle changes in health (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2000; Houx, Jolles, & Vreeling, 1993; Van Boxtel et al., 1998; Van Boxtel et al., 2000). For these reasons, these tests were used in this study.

The Stroop Colour-Word Test (SCWT) is a measure of selective attention and speed of information processing. This test involves three cards displaying 100 stimuli each (Houx & Jolles, 1993; Stroop, 1935). The first card contains colour words printed in black ink, which have to be read aloud. The second card contains coloured patches, which have to be named. The last card displays colour names printed in incongruously coloured ink. Participants are instructed to name the ink colour of the printed words. By subtracting the time needed for the last part from the mean score of the first and second parts (SCWT-12), an interference score can be calculated (SCWT-i). This interference score is a measure of inhibition of a habitual response, which can be considered an aspect of executive functioning.

The Concept Shifting Task (CST) is a modified version of the Trial Making Test (Vink & Jolles, 1985) and is used to measure simple cognitive speed and cognitive flexibility. It consists of three parts. On each test sheet, 16 small circles are grouped in a larger circle. The smaller circles contain numbers, letters or both, appearing in a fixed random order. Participants are requested to cross out the items in the right order. In the last part, participants have to alternate between numbers (1-8) and letters (A-H). The scores correspond to the time needed to complete each trial. The difference between the last part (CST-c) and the mean score of the first and second parts (CST-ab) is considered to reflect the additional time needed to shift between both sets of stimuli (CST-i).

Intentional learning and verbal memory functioning were measured using the Visual Verbal Learning Test (VVLT). Fifteen monosyllabic words are presented one after another and subjects are asked to recall as many words as possible. This procedure is repeated five times (Brand & Jolles, 1985). To preclude ceiling effects that may become apparent in the last two trails, the total score of the first three trails is used as dependent variable. After 20 minutes, delayed recall is tested.

Cognitive compound scores

Selected raw scores for cognitive tasks were clustered in three domains (sensorimotor speed, memory, and executive functioning) to yield compound cognitive scores. This was done to reduce the number of cognitive variables, while improving the robustness of the underlying cognitive construct (Lezak, 1995). Raw scores were transformed to Z-scores in the total group of participants that were selected in this study. The average was calculated of the Z-transformed scores that were included in a compound index. The memory compound score included the immediate and delayed recall of the VVLT. The sensorimotor speed compound score was derived from the first and second subtask of the SCWT and CST. The executive functioning compound score was calculated using the interference scores of the SCWT and CST. The signs of the sensorimotor speed and executive functioning compound scores were inverted to make them reflect above average performance when positive and below average performance when negative (Van Boxtel et al., 1998).

Functional status

Functional status was measured using the SF-36 questionnaire, which contains 36 multiple-choice questions (Ware & Sherbourne, 1992). The SF-36 is coded into eight scales: physical functioning, social functioning, role limitations due to physical problems, role limitations due to emotional problems, general mental health, vitality, bodily pain, and general health perceptions. Each scale can range from 0 (lowest level of functioning) to 100 (highest level). These eight scales can be summarized into physical (PCS) and mental components summary measures (MCS) (Ware, Kosinski, & Keller, 1994). Low scores imply a low level of functioning and the average of this score in the general US population is 50 (Ware et al., 1995). At the baseline measurement, the SF-36 was administered to two out of four participant panels only (n=300 in age 60 and older group). At the 3-year follow-up, nearly all participants in this age range filled in the SF-36 (n=485, 92%). In total, 386 persons filled in the SF-36 during the second follow-up measurement.

Other measures

Age, sex, and level of education were considered potential confounders. Level of education was indexed on an 8-point ordinal scale: 1=primary education, 2=lower vocational education, 3=intermediate general secondary education, 4= intermediate vocational education, 5=higher general secondary education/ university preparatory education, 6=higher vocational preparatory education, 7=higher professional education, 8=university education (De Bie, 1987).

Data analysis

To maximize the number of observations and acquire the highest power, cross-sectional analyses were based on available data at the first follow-up evaluation and the longitudinal analyses included data from the 3-year and 6-year follow-up evaluations. Means and standard deviations of the summary scores of the SF-36 were computed and compared between the first and second follow-up, using paired t-tests. Associations between the cognitive compound scores for the 3-year follow up and the SF-36 summary score for the 3- and 6-year follow-ups were first examined with correlation analysis (Pearson's *r*). Subsequently, linear regression analysis was performed in order to analyse whether cognitive compound scores were cross-sectionally related to SF-36 summary scores. These analyses were adjusted for age, sex, and educational level. Next, the cognitive compound scores were analysed as predictors of a change in SF-36 summary scores 3 years later, again using linear regression analysis adjusted for age, sex, educational level, duration of follow-up interval, and SF-36 summary score at baseline. All analyses were performed using SPSS for Macintosh program series, version 10 (SPSS-Inc., Chicago), with a p-level of 0.05.

Results

The PCS decreased from 46.7 to 44.9 after 3 years ($t=4.40$, $p<0.01$), however, the MCS showed no change ($t=0.52$, $p=0.60$). The three cognitive compound scores at the 3-year follow-up were significantly correlated with the PCS at 3-year follow-up (zero-order Pearson's r for sensorimotor speed, memory, and executive functioning were 0.24, 0.13, and 0.25, respectively) and again at the 6-year follow-up (Pearson's r for sensorimotor speed, memory, and executive functioning were 0.24, 0.11, and 0.20, respectively). A different pattern was observed for the MCS. The three cognitive measures at the 3-year follow-up were correlated with MCS at the 3-year follow-up (sensorimotor speed: 0.21; memory: 0.10; executive functioning: 0.13), but not at the 6-year follow-up (sensorimotor speed: 0.09; memory: 0.08; executive functioning: 0.06, all $p>0.05$).

Although not consistently evident for all cognitive summary scores, overall cognitive functioning was significantly related with both summary scores of the SF-36 in the cross-sectional regression analyses (Table 1). Higher scores on the cognitive compound measures were associated with higher scores on the SF-36, even after adjusting for age, educational level, and sex.

Cognitive functioning was not associated with SF-36 summary scores 3- or 6-years later (Table 1). Thus, older persons with good cognitive functioning at baseline did not experience less decline on SF-36 scores compared with persons with poor baseline cognitive function, independent of their baseline SF-36 score. Essentially the same results were found when the longitudinal analyses were repeated in the smaller group that was available from baseline to 6-year follow-up (results not tabulated).

Table 1. Cross sectional and longitudinal association (standardised regression coefficients) between cognitive functioning and 3-year change in SF-36 summary scores

	Cross sectional analyses		Longitudinal analyses	
	PCS	MCS	PCS	MCS
	β	β	β	β
Sensorimotor speed	0.15**	0.11*	0.01	0.04
Memory	0.06	0.20**	0.05	0.01
Executive functioning	0.16**	0.13*	0.03	0.01

PCS = physical component scale; MCS = mental component scale

Note: Cross-sectional analyses were adjusted for age, sex, and educational level. Longitudinal analyses were adjusted for age, sex, educational level, length of follow-up interval and cognitive functioning at baseline

*p<.05; **p<.01

Discussion

The aim of this study was to investigate whether cognitive functioning was related to functional status in older healthy adults. The cross-sectional findings indicated that cognitive performance was associated with functional status. Individuals with a low level of cognitive functioning had a lower functional status than individuals with a high level of cognitive functioning. The question whether cognitive performance has predictive power for functional decline was answered in the negative: low cognitive performance at baseline did not predict more functional decline 3 or 6 years later.

The cross-sectional relationship between cognitive and functional status variables has been reported earlier. It has been argued that this association can be explained, at least in part, by the presence of depressive symptoms, because depression or depressive symptoms are related to cognitive functions, notably memory, attention, and executive disorders (Austin, Mitchell, & Goodwin, 2001; Burt, Zembar, & Niederehe, 1995; Den Hartog, Derix, van Bemmel, Kremer, & Jolles, 2003). In an earlier study, SF-36 scores were lower in depressed patients than in non-depressed controls (Doraiswamy, Khan, Donahue, & Richard, 2002). We therefore performed additional post hoc regression analyses in which depressive symptomatology, measured with the depression scale of the SCL-90 (Arrindell & Ettema, 1986) was controlled for. The cross-sectional relation between the PCS and the executive compound score was attenuated, but still significant after adjusting for depressive symptoms ($p<0.01$). However, the relations between the MCS and the three cognitive domains and that between the PCS and sensorimotor speed were no longer significant, after adjusting for depressive symptoms. Thus, depressive symptomatology may act as a confounder in the relation between cognitive functioning and functional status, but does not explain the cross-sectional relation between executive functioning and SF-36 PCS.

The population investigated in this study consisted of community dwelling older adults. These participants functioned at a normal level with respect to functional status as well as cognitive functioning. Therefore it was not surprising that the results of the present study demonstrated a small decrease in functional status over a 3-year interval. A longer time lag and therefore a larger decrease in functional status may be needed to demonstrate a longitudinal association between cognitive functioning and functional status. Or a reverse causation (i.e. functional status as a predictor of cognitive decline) may be present.

Comparison of the associations between different cognitive functions showed that the strongest cross-sectional relation was that between functional status and executive functioning. These findings are in line with previous cross-sectional studies that focused on (I)ADL, which have shown that performance on tests of executive functioning is more strongly related to functional impairment than other cognitive functions, including memory, language, visuospatial skills, and psychomotor speed (Bell-McGinty et al., 2002; Cahn-Weiner et al., 2002; Cahn-Weiner et al., 2000; Carlson et al., 1999; Grigsby et al., 1998). This could be taken as evidence to support the importance of executive functions to functional status, because these functions involve relatively complex behaviour, including activities related to planning, problem solving, anticipation of possible consequences of an intended course of action, and inhibition of irrelevant information (Lezak, 1995).

In conclusion, poor cognitive performance was related to poor functional status at the actual moment of testing. This association could be mediated by secondary factors, such as depressive symptomatology or life events, since cognitive functioning did not prove to be predictive of functional status 3 or 6 years later. The practical implication is that, in clinical practice, neuropsychological findings can indeed contribute to answering questions concerning the current functional status of an older person. Alternately, it is worthwhile to stress that inferences from neuropsychological assessment for functional status in the future are not valid in a normal aging population and may be influenced by an underlying depression or a bias due to negative affectivity.

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Part II

Interventions

Chapter 6

Effect of a structured course involving Goal Management Training in older adults: A randomised controlled trial

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Abstract

The objective of this study was to investigate the effect of a 6-week (12 sessions) structured course on the executive functioning of older adults. The course was based on the principles of 'Goal Management Training' and involved training in combination with psycho-educational techniques. The aim of this intervention was to teach individuals a strategy to improve their efficacy and attitude towards planning activities and to structure intentions. Sixty-nine community dwelling older individuals aged 55 years and older were randomised to a treatment group or a waiting list control group. After the intervention, the participants in the intervention group were significantly less annoyed by their cognitive failures and better able to manage previously reported executive failures than were controls. There were no effects on objective measures of cognitive functioning. The findings of this study indicated that a combination of psycho-education and training has the potential to change the attitude of older individuals towards their functioning.

Introduction

Most cognitive functions decline with age. Working memory functions less well (Van der Linden, Bredart, & Beerten, 1994), inhibitory mechanisms become less efficient (Persad, Abeles, Zacks, & Denburg, 2002; Zacks & Hasher, 1997), and performance in dual task situations is reduced (Glass et al., 2000). Interestingly, working memory, inhibition, and shifting between two tasks are frequently seen as aspects of executive functioning (Miyake et al., 2000). This is important because executive functioning is a basic condition for everyday functioning of older adults and poor executive functioning may even affect independent living and successful aging (Cahn-Weiner, Boyle, & Malloy, 2002; Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998; Rowe & Kahn, 1997). For example, older people may experience difficulties in planning their leisure time activities, managing their finances, coping with novel situations, or learning to deal with new strategies and procedures, such as using computers, Internet services, cellular phones and other electronic devices. All these activities require that the proper goal is selected and maintained in memory while the task is executed. In addition, when performing such complex tasks, it is important to be able to divide the task into simpler tasks and to set priorities for the execution of subordinate goals (De Jong, 2001; Duncan, 1986). Although many older adults experience difficulties with planning activities, the effect of neuropsychological interventions to improve these cognitive functions in older adults has not yet been investigated. Most neuropsychological interventions for older individuals focus on memory functioning and recently also memory self-efficacy (e.g. Commissaris, Verhey, & Jolles, 1996; Valentijn et al., in press). It is therefore a challenging opportunity to examine whether older individuals benefit from an intervention directed at executive functions, notably organization and planning of activities in daily life.

The intervention protocol of Goal Management Training (GMT Robertson & Levine, 2000), was originally developed to teach patients with brain injury a strategy to improve their ability to plan activities and to structure intentions. The GMT was based on the theoretical framework of disorganization of behaviour (Duncan, 1986; Duncan, Emslie, Williams, Johnson, & Freer, 1996). This theory states that any line of activity requires a list of goals or task requirements that are used to create a structure of actions or mental operations by which these goals are achieved. In performing a task, the current state of affairs and the goal state are compared, and appropriate actions or mental operations are selected in order to reduce any mismatch. This continues until there is no mismatch between the current state and the goal state. Given that the number of actions that can actually be performed at any one time is limited, it is important to inhibit irrelevant actions that will not contribute to a particular goal. The GMT contains several stages that are based on this notion. First, participants have to be aware of the current state of affairs (“stop”). Then the appropriate goals have to be selected (“what do I have to do?”), and if needed goals have to be partitioned into subordinate goals (“split”). In the final stage (“checking”), the outcome of the selected actions is compared with the goals to be achieved. The GMT has been evaluated in 30 patients with mild to severe brain injury, who were randomly assigned to groups who received GMT or motor skill training. Participants who followed the GMT showed significant gains on everyday paper-and-pencil tasks designed to mimic tasks that are problematic for patients with executive problems (Levine et al., 2000).

Since the problems and topics used in the GMT are also applicable to older adults, we developed a dedicated structured course based on the GMT for use in older adults. The course consists of 12 sessions (two sessions per week). Apart from the GMT, psycho-education was an essential part of the intervention. Using a randomised controlled trial with a waiting list control group, we examined whether this intervention was effective in older adults in reducing complaints and cognitive failures and in improving cognitive functioning. During the course, participants practised real life activities, with emphasis on the complaints and problems experienced by the participants. We therefore expected that the training would have more impact on complaints and cognitive failures participants experienced rather than on actual cognitive performance.

Methods

Participants

The participants were recruited through media advertisements asking for people aged 55 years and older with complaints about their cognitive functioning to participate in the study. Participants were enrolled if they had a score of 24 or more on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), had a good comprehension of the Dutch language, were mobile enough to travel independently to the research centre, and had not previously participated in a neuropsychological research programme. People with documented evidence of neurological diseases of the central nervous system (e.g. dementia or Parkinson's disease) or a major psychiatric disorder were excluded. The local medical ethics committee approved the study and all participants gave their informed consent.

Goal Management Course

The Goal Management Training (GMT) was originally developed for brain-injured patients (Levine et al., 2000; Robertson & Levine, 2000). The aim of this structured and interactive intervention is to teach individuals a strategy to improve planning activities and to structure intentions. We translated the training manual into Dutch and adapted the content to make it applicable to healthy older people with executive problems. One major addition to the GMT concerns a substantial place for 'psycho-education', i.e. an explanation of the various cognitive functions and their role in normal behaviour and in problems in daily life. In addition, the programme was adapted to consist of twelve sessions, one individual session and eleven group sessions. The content of each session and the order in which topics were addressed were structured in a protocol. The group sessions involved two trainers, a healthcare psychologist with ample experience in interventions for people with cognitive problems and a research psychologist. Each group consisted of maximally seven participants, to ensure that the training group could function optimally. The groups were homogeneous with respect to sex, since the complaints reported by women and men, apply to different situations and topics (e.g. shopping versus technical maintenance). There were 10 female and 2 male groups. Each session lasted 1 to 1.5 hours and there were two sessions a week, for 6 consecutive weeks. A structured trainer manual was available, describing the text and actions to be used by the trainer. The trainer incorporated examples which had been put forward by the participants as frequently as possible and stimulated initiative and active participation in this respect. All sessions were structured – homework and last week's topics were discussed first, and each participant had to report at least one failure and one success in daily life (25-35 minutes). The accompanying emotional experience was specifically addressed in the group in each session. Then information about a new stage of the strategy was introduced or a stage that was discussed in a previous session was extended (25-35 minutes). At the end of each session, participants received homework exercises and handouts containing a summary of the session (10 minutes). All topics were illustrated with practical examples or exercises.

The goals for the first two sessions were getting acquainted with the trainer and the rest of the group and with the goals of the course, discussing the expectations of the training, and increasing insight into the complaints about executive functioning, for example by discussing examples of complaints. In the third and fourth sessions, high-risk situations were identified, the stop strategy was introduced using an automatic pilot metaphor and a personal catchphrase was chosen (e.g. 'just a second' or 'wait a minute'). The stop strategy was extended in session five by means of a relaxation technique and a discussion of cognitive information processing and working memory. In the individual session, personal problems and expectations about the course were discussed, additional questions about the training were answered, and the interaction with the other course participants was discussed. Sessions seven and eight focused on stating a goal. Furthermore, inhibition of relevant goals and conflicting goal scenarios were main topics in these sessions. Sessions nine and ten were used to discuss splitting a complex task into subgoals and then to prioritise these subgoals. The topic of session eleven was the checking construct. Finally, in the last session an overview was given.

Outcome measures

The outcome variables were obtained from a test battery that included subjective and objective cognitive tests.

Subjective executive functioning

The Cognitive Failure Questionnaire (CFQ) was used to evaluate subjective executive functioning. This instrument consists of 25 items measuring the frequency of everyday cognitive 'failures' in the area of memory, attention, perception and action (Broadbent, Cooper, FitzGerald, & Parkes, 1982; Merckelbach, Muris, Nijman, & de Jong, 1996; Ponds, Commissaris, & Jolles, 1997). Participants were asked to indicate on a 5-point scale how often they usually experienced each particular cognitive failure (never, very rarely, occasionally, quite often, and very often). A higher score on the CFQ indicates more cognitive failures. The CFQ has been validated in Dutch.

Perceived degree of hinder, worry, and annoyance about subjective executive functioning were scored with the questionnaire used in the Maastricht Aging Study (MAAS; Jolles, Houx, van Boxtel, & Ponds, 1995), a longitudinal study on normal cognitive aging. This questionnaire contained four questions focusing on the perceived degree of hinder, worry, and annoyance about these failures. Each question has five possible answers ranging from 'not at all' to 'a lot'.

Management of reported executive failures was evaluated using the following instrument. On the basis of information from the screening interviews, ten complaints were selected that were reported most often by the participants with executive complaints (e.g. doing more than one activity at a time, performing activities according to a plan, estimating the time needed for an activity). Participants scored each item on a scale ranging from 1 ('cannot manage this at all') to 10 ('have no problems at all'). The ten values were summed to compute a total score, ranging from 10 to 100. Cronbach's alpha for this 10-item instrument was 0.68, based on data from the baseline measurements.

Objective test performance

The Stroop Colour Word Test (SCWT) involves three cards displaying forty stimuli each (Houx, Jolles, & Vreeling, 1993; Stroop, 1935). The first card contains colour words printed in black ink, which have to be read. The second card contains coloured patches, which have to be named.

The third card displays colour names printed in incongruously coloured ink. Individuals are instructed to name the ink colour of the printed words. By subtracting the time needed for the last part from the mean score of the first and second part, an interference score can be calculated, that was used as an outcome measure. This interference score can be regarded as a measure of inhibition of a habitual response, which depends on adequate levels of executive functioning (Hanninen et al., 1997).

Other measures

Four subtasks of the Groningen Intelligence Test (GIT) were used to make a reliable estimation of IQ (Luteijn & van der Ploeg, 1983). The four subtasks involved were: 1) Arithmetic: the correct completion of as many addition sums as possible in 1 minute, 2) Vocabulary: indicating which of five alternative words is exactly synonymous with a given word, 3) Visuoconstruction: indicating which two-dimensional shapes from a larger set are needed to exactly fill up a given space, and 4) Verbal reasoning: indicating which of five alternatives is related in the same way to a given word as two words in an example.

Level of education was indexed on an 8-point ordinal scale: 1=primary education, 2=lower vocational education, 3=intermediate general secondary education, 4= intermediate vocational education, 5=higher general secondary education/ university preparatory education, 6=higher vocational preparatory education, 7=higher professional education, 8=university education (De Bie, 1987).

The Mini-Mental State Examination (MMSE; Folstein et al., 1975) was used as a screening instrument for dementia, and consists of the scales orientation, registration, recall, attention, language, and construction. A maximum score of 30 can be obtained.

Procedure

A dual baseline and two follow-up assessments were used in this randomised controlled trial. Before the first measurement, all participants were screened for executive complaints and problems by means of a structured interview. Demographic variables, complaints about cognitive functioning, and information from significant others were obtained. Furthermore, participants were asked to evaluate their ability to prepare and plan several activities, such as planning a party, preparing a vacation, and operating a mobile phone. Information obtained from this screening protocol was used to select individuals who would benefit from the training and to exclude individuals who experienced memory problems only, who did not have any cognitive complaints or problems, who wanted to prevent cognitive problems in the future, who had pathological cognitive problems (dementia), or who had cognitive complaints or performance deficits in other cognitive domains (e.g. Mild Cognitive Impairment; Jolles, Verhey, Riedel, & Houx, 1995; Petersen et al., 2001). Based on this structured interview, persons were selected who experience executive problems (e.g. being chaotic, distractible, having problems to concentrate, unable to perform activities according to a plan) to participate in the study. If it was uncertain whether a person had executive complaints or problems, the case was referred to an experienced clinical neuropsychologist (RP). After screening, participants were randomly assigned to the intervention group or waiting list control group. The method of randomisation was a block design with block size two, and with stratification for age and sex. The investigator who was responsible for randomisation was not involved in the training procedures. All participants (training group and control group) were tested twice, before the intervention group received the intervention. This 'dual baseline procedure' was used in order to reduce the (procedural) learning effect. The mean interval between measurement 1 and measurement 2 was 17 days (SD=5.8). Both the control group and the intervention group were tested immediately after the intervention group had completed the intervention, which was 8 weeks after measurement 2. The fourth measurement (long term effect) took place 7 weeks later. All the statistical analyses were performed using data for the second baseline assessment and the two subsequent follow-up measurements.

Statistical analyses

First, we examined whether this study population indeed experienced more cognitive failures (CFQ total score and additional questions) and had a lower score on the interference score of the SCWT than a general population. Using Student t-tests, we compared the baseline performance on these outcome measures of the participants in this study with that of age-, sex-, and education-matched healthy individuals who participated in the Maastricht Aging Study.

Although the participants were randomly assigned to the two groups, possible differences could exist between the study groups by chance. Therefore, differences in demographic characteristics (age and education), intelligence, and MMSE score between the two groups were examined using Student t-tests. A Chi-square test was used to analyse group differences with respect to sex and marital status (married/cohabiting versus others). General Linear Model (GLM) with repeated measures analysis of variance was used to examine the effects of the intervention. Analyses were performed with group (two levels: intervention group, control group) as between-subject variable and time (two levels: first follow-up and second follow-up) as the within-subject factor. Baseline scores at measurement 2 were treated as covariates in this model to control for baseline group differences. Consistent with the rules for clinical trails, all analyses were based on the groups as randomised, according to the principle of 'intention-to-treat', i.e. all participants were analysed in the groups to which they were originally randomised, regardless of whether they had received or adhered to the allocated intervention (Altman et al., 2001). Analyses were performed using the SPSS for Macintosh program series, version 10 (SPSS-Inc., Chicago), with $p=0.05$ as significance level.

Results

Recruitment of participants

Two hundred and eleven people aged 55-82 were screened for participation. Of these, 106 were excluded: 82 had no executive problems or complaints, 18 had already participated in a neuropsychological research program, 5 were younger than 55 years, and 1 had limited mobility. Thirty-six adults refused to participate after reading the informed consent or after the screening due to insufficient motivation or interest. Sixty-nine participants were randomised to the intervention or control group. The intervention group started with 38 persons, of whom 35 received the training and 3 persons decided after assignment not to start with the intervention, but who stayed in the study and provided follow-up data. Main reasons for not starting the course were health-related problems or being too busy with other activities or work. After the dual baseline, one person in the intervention group dropped out because of illness. The control group consisted of 31 participants. One person of the control group refused to participate after the dual baseline measurement, because of a lack of interest. Thus data for 37 people in the intervention group and 30 people in the control group were analysed. Results of recruitment and randomisation are given in Figure 1. Post hoc power analysis on the available number of participants using a medium critical effect size of 0.15 and an alpha level of 0.05 resulted in a power of 0.88 for this study (Buchner, Faul, & Erdfelder, 1992).

Comparison with participants from the Maastricht Aging Study

After matching for age (2 groups), sex and education (2 groups), the study participants reported more cognitive failures on the CFQ total score ($t(1,134)=7.23$, $p<0.01$), hindrance ($t(1,134)=7.66$, $p<0.01$), worry ($t(1,134)=5.98$, $p<0.01$), and more annoyance ($t(1,134)=5.13$, $p<0.01$) about these failures than did participants enrolled in the Maastricht Aging Study. In addition, they had worse scores on the interference score of the Stroop Colour Word Test ($t(1,132)=3.63$, $p<0.01$).

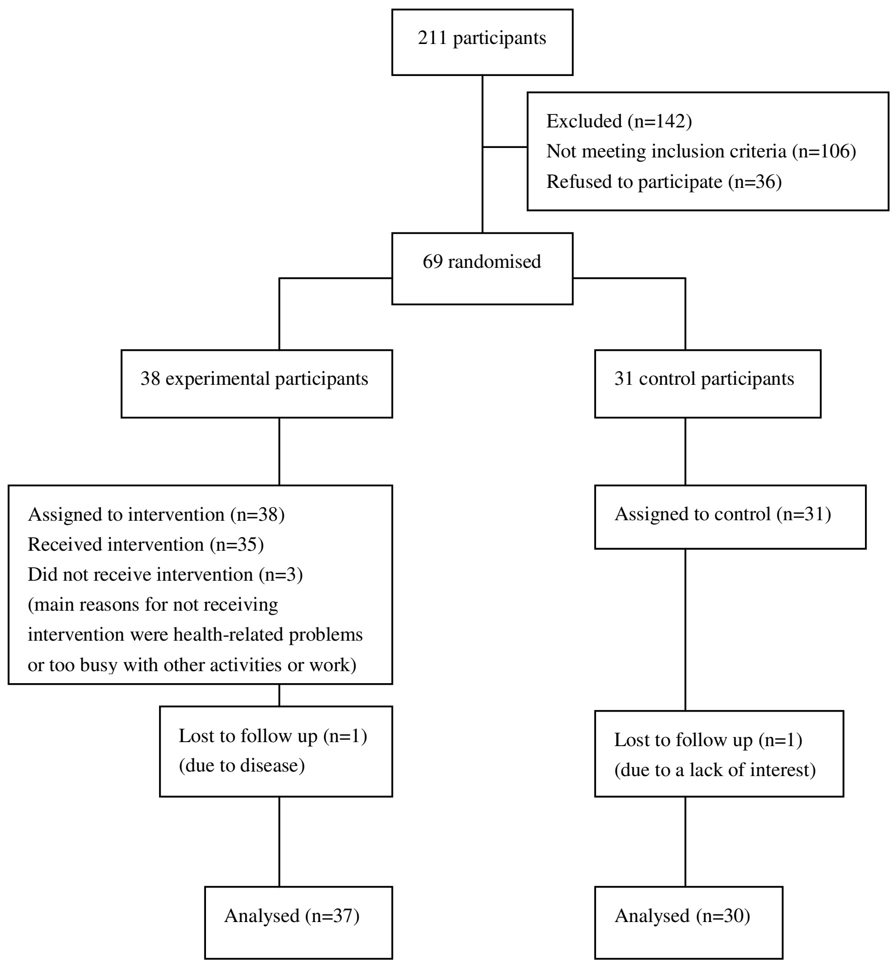

Figure 1. Flowchart of the participants

Baseline characteristics

Demographic characteristics and mean MMSE and IQ scores are summarised in Table 1. The intervention group and the control group did not differ on age (t(1,67)=-0.65, p=0.52), sex (Chi-square=0.06, p=0.81), educational level (t(1,67)=-0.43, p=0.67), marital status (X^2=0.01, p=0.94), or MMSE score (t(1,67)=-1.27, p=0.21). The IQ scores of the intervention group were slightly, but significantly, lower than those of the control group (t(1,67)=-1.99, p=0.05).

Table1. Demographic characteristics of the participants in the study

	Experimental	**Control**	**p-value**
N	37	30	
Age	62.4 (5.4)	63.3 (5.9)	0.52
Sex *(% women)*	82%	83%	0.81
Education	3.6 (1.8)	3.8 (2.0)	0.67
Marital status *(% living together/married)*	68%	67%	0.94
IQ	113.7 (12.7)	119.4 (10.3)	0.05
MMSE	28.5 (1.3)	28.9 (1.4)	0.21

MMSE= Mini Mental State Examination

Note: Student t-tests were used for age, education, intelligence and MMSE-score. Sex and marital status were analysed using Chi-square test

Effects of the Goal Management Training

The intervention group experienced less annoyance after the training than did the control group (F(1,62)=5.94, p=0.02, see Table 2). Interaction effects were not significant (F(1,62)=0.05, p=0.82), indicating that the intervention effect was already present immediately after the intervention and did not change after 7 weeks of follow-up. Furthermore, participants in the intervention group were better able to manage executive failures after training (F(1,63)=4.28, p=0.04). The interaction effect was not significant (F(1,63)=0.84, p=0.36); thus there was no difference between the first follow-up measurement and the second follow-up measurement. The total score on the CFQ, and the additional questions concerning hindrance and worries about cognitive failures did not significantly improve after participants followed the training compared to control participants. The intervention had no effect on the interference score of the SCWT (F(1,63)=0.01, p=0.91) and there was no interaction effect (F(1,63)=0.83, p=0.34), which suggested that both at short and long term the intervention had no effect on the interference score of the SCWT.

Table 2. Adjusted means, standard error of the mean (SEM) and results of tests for group differences of the subjective measures and objective test performance.

	Short-term post-intervention	**Long-term post-intervention**	**Main effect**	**Interaction effect**
	Mean (SEM)	Mean (SEM)	p-value	p-value
Subjective measures				
CFQ total score				
Experimental	40.29 (1.43)	40.83 (1.40)	0.21	0.98
Control	42.81 (1.60)	43.38 (1.56)		
CFQ hindrance				
Experimental	2.84 (0.10)	2.76 (0.11)	0.29	0.55
Control	2.93 (0.11)	2.95 (0.12)		
CFQ worries				
Experimental	2.67 (0.11)	2.62 (0.11)	0.19	0.11
Control	2.99 (0.12)	2.65 (0.12)		
CFQ annoyance				
Experimental	2.37 (0.14)	2.49 (0.15)	0.02	0.82
Control	2.81 (0.15)	2.98 (0.17)		
Executive complaints[a]				
Experimental	63.35 (0.91)	62.21 (0.93)	0.04	0.36
Control	60.19 (1.03)	60.13 (1.05)		
Objective test performance				
SCWT interference				
Experimental	19.63 (0.93)	21.07 (0.96)	0.85	0.18
Control	20.92 (1.09)	20.25 (1.09)		

CFQ = Cognitive Failure Questionnaire, SCWT = Stroop Colour Word Test

Follow-up group differences were analysed using Analysis of Variance, adjusted for baseline score

[a] Higher score reflect less complaint about executive functioning

Additional analyses were performed to adjust for the small but significant difference in IQ between the two groups. A similar pattern of results was found: participants in the intervention group experienced less annoyance ($F(1,61)=5.22$, $p=0.03$) and were better able to manage executive failures ($F(1,62)=4.32$, $p=0.04$) after the training than the did control participants. Again, no interaction effects were found, indicating that the intervention effect already present immediately after the intervention did not change after 7 weeks follow-up.

Discussion

The aim of this study was to evaluate a structured course for older adults that included the principles of GMT and psycho-education, using a randomised controlled design. After the intervention, participants in the training group were better able to manage previously reported cognitive failures and were less annoyed by cognitive failures than were participants in the waiting list control group. Participants who had received the intervention reported that they were better able to perform activities according to a plan, to estimate the time needed for an activity, and they were less distracted during an everyday activity. Thus after being taught to identify situations characterized by a risk of cognitive failure and to state appropriate goals when confronted with such situations, the trained participants appeared to be better able to structure activities in daily life and to work according to a plan. Training effects were not reflected by an improved objective test performance: Stroop Colour Word Test interference score did not improve after training. Thus, subjective aspects appear to be more important than objective test performance. Accordingly, strategies to cope with cognitive dysfunctioning and attitudes toward cognitive problems did improve. This finding may be important for health care, because many community-dwelling older adults experience cognitive complaints and therfore may seek medical attention unnecessarily.

In the present study, we accounted for several methodological drawbacks that have flawed previous cognitive intervention studies. First, the large number of participants who were included ensured sufficient 'power' to detect medium-sized intervention effects. Most previous intervention studies included fewer participants (e.g. Rasmusson, Rebok, Bylsma, & Brandt, 1999; Rebok, Rasmusson, Bylsma, & Brandt, 1997; Schmidt, Zwart, Berg, & Deelman, 1999, N=46, N=32, and N=45 respectively). Secondly, a randomised controlled design was used, which provides the best evidence about the efficacy of health care interventions (Altman et al., 2001). Up till now, this type of design has been used only occasionally in studies of behaviour modification (e.g. psychotherapy) despite its great advantages. Thirdly, in order to estimate the effects of allocating an intervention in clinical practice, the data were analysed on an intention to treat basis. This analysis avoids the bias associated with non-random loss of participants (Altman et al., 2001). Fourthly, people with cognitive impairments and major depression were excluded, and therefore resulted in a homogeneous group of older adults. In addition, single sex treatment groups may have optimised group processes. In short, this study accounted for many problems that previous studies have failed to deal with adequately.

The intervention diminished hindrance and improved the management of reported executive problems, but the effect sizes were relatively modest. Levine et al. (2000) found that the intervention significantly improved objective cognitive performance (on paper and pencil tests), whereas we did not. One explanation for this finding is that these older adults were not as impaired as patients with brain injury, and therefore their capacity for improvement may have been more limited. Another explanation is related to problems that may be encountered when using executive tests for the purpose of treatment evaluation. First, cognitive tests may not be sensitive enough to detect intervention effects that focus on various aspect of behavior, notably executive functioning. Second, because objective performance on cognitive tests appears not to be related to subjective cognitive functioning (Bolla, Lindgren, Bonaccorsy, & Bleecker, 1991; Commissaris, Ponds, & Jolles, 1998; Ponds & Jolles, 1996). It should be remembered that objective and subjective functioning do not necessarily both change after an intervention. The participants reported feeling less annoyed with their failures, which suggests that they may have changed their coping strategies, as reported earlier (Commissaris et al., 1996). Thirdly, the available executive tests with high ecological validity, such as the Behavioral Assessment of the Dysexecutive Syndrome (Wilson, Alderman, Burgess, Emslie, & Evans, 1996), require that the test is novel for the participants, which implicates that no valid scores can be obtained when these tests are administered on 2 or more occasions a few weeks apart. Thus, these tests are not suitable for the measurement of change in a design as used in the present study.

The participants of this study were selected on problems with executive functions, such as being chaotic and disorganised, and being often distracted, etc. They all reported more cognitive failures, more annoyance, hinder and worry about these failures than age-, sex- and education-matched people from the Maastricht Aging Study. In addition, they were more sensitive to interference on the Stroop Color Word Test. This indicates that we indeed have selected a group of older adults who experienced cognitive failures and who may be less able to cope with these problems. Based on extensive evaluations by the trainers, it appears to be very important to select persons with executive problems and who have adequate insight into their problems in order to benefit from such a training programme. In our opinion, individuals who do not experience difficulties with their executive functions may not recognize, and therefore not apply, the problems and items that are discussed during training. People with less insight into their functioning may not be able to apply the strategy, in particular the stop stage that requires insight into the problem when cognitive failures occur.

In conclusion, the structured course based on the GMT tested in this study appears to improve the ability of older people who experience cognitive problems to manage executive failures and to be less annoyed with cognitive failures. As the intervention was relatively short, with 12 sessions, and because the subjective evaluation of the people after training was quite favourable, the intervention can be considered a valuable contribution to cognitive interventions for older adults. Moreover, the finding that executive functions, such as planning activities, performing multiple tasks, and managing novel situations, are among the first functions to decline in older people makes it important to develop an effective intervention that addresses the problems associated with a failure of executive function.

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Chapter 7

Does cognitive function in older adults with hearing impairment improve by hearing aid use?

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Abstract

In the present study, the effects of hearing aid use by hearing-impaired older individuals were investigated on different aspects of cognitive function, such as memory, attention, executive functioning, and processing speed. Fifty-six participants who were fitted with hearing aids for the first time were compared with 46 control participants with an equivalent hearing impairment, but who were not fitted with a hearing aid. After a dual baseline measurement and fitting of the hearing aids, all participants were assessed again with neurocognitive tests after 12 months. While the participants with hearing aids had improved aided hearing thresholds, they did not demonstrate an improved performance on the cognitive tests compared to the controls. Thus improved hearing did not improve cognitive functioning. These findings may suggest that hearing aid use only restores impairments at the level of the sensory organ, but does not affect the central nervous system and, as a consequence, cognitive functioning.

Introduction

The prevalence of hearing impairment increases sharply with age and this condition affects at least 30% of all people aged 65 to 75 years in the United States (Cruickshanks et al., 1998). Unfortunately, a large number of elderly people are not, or not adequately, treated for this disability, which may negatively affect daily life or cognitive functioning. Indeed, in the past decades, research has indicated that hearing impairments can interfere with cognitive abilities and intellectual functioning (Baltes & Lindenberger, 1997; Cacciatore et al., 1999; Lindenberger & Baltes, 1994, 1997; Naramura et al., 1999; Van Boxtel et al., 2000). For example, Lindenberger et al. (1994) demonstrated that both auditory acuity and visual acuity were positively related to sensorimotor speed, memory, vocabulary, fluency, and reasoning in 156 individuals who were 70 years and older (Lindenberger & Baltes, 1994). Van Boxtel et al. (2000) reported similar findings in their study that investigated the relation between auditory functioning and verbal memory performance in 453 individuals aged between 23 and 82 years.

The negative relationship between sensory and cognitive measures may be explained by a common factor, for instance neurodegenerative processes. Thus, the correlation between sensory functioning and cognitive ability may increase in old age, because both are affected by age-related physiological changes in brain function (Anstey, Luszcz, & Sanchez, 2001; Lindenberger & Baltes, 1994, 1997). It has been postulated that a prolonged lack of adequate sensory input may reduce opportunities for intellectually stimulating exchanges with the environment and could result in a reduced efficacy of neural networks involved in cognitive abilities, for example, through a loss of synaptic connectivity or neuronal atrophy (Lindenberger & Baltes, 1994; Sekuler & Blake, 1987).

Despite interest in the association between hearing impairment and cognitive dysfunction, only two studies have investigated whether improvement of hearing in older adults by the use of hearing aids improves cognitive performance compared with that of hearing-impaired individuals not using hearing aids (Mulrow et al., 1990; Tesch-Romer, 1997). In a randomized-controlled trial, Mulrow et al. (1990) investigated 194 adults older than 64 years, 99 of whom were fitted with a hearing aid. After 6 months, the hearing aid group had a significantly better performance than the control group on a general cognitive measure (Short Portable Mental Status (Pfeiffer, 1975)). In contrast, Tesch-Romer (1997), in their study of people aged between 51 and 87 years with mild-to-moderate hearing loss who were fitted with a hearing aid (n = 70) and two age-matched control groups (hearing-impaired control group without hearing aids, n = 42, approximately normal hearing control group, n = 28), found no improvement of performance on speed, vocabulary, and fluency tasks in the hearing aid group after 6 months. Thus, so far, the studies that examined the effects of improved hearing on cognition have yielded contradictory results.

The present controlled intervention study investigated a broad range of cognitive domains that had previously shown positive associations with auditory acuity in cross-sectional studies of older adults (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994; Van Boxtel et al., 2000), using cognitive tests that are particularly sensitive to aging. These cognitive tests were all presented in their standard sensory mode, i.e. visually. The abovementioned studies measured cognitive function about 6-month after hearing aids were fitted, because habituation to hearing aid use stabilizes after about 6 month (Henrichsen, Noring, Lindemann, Christensen, & Parving, 1991). However, we assessed cognitive performance later, at 12 months. This choice was based on the assumption that the effect of hearing aid use on cognitive performance may need additional time before restoration of degraded neural circuits is achieved by the restored auditory input (e.g. Robertson & Murre, 1999).

In summary, the main aim of the present study was to examine whether hearing aid use in older adults improved cognitive function 12 months later compared to that of persons not using hearing aids. If hearing aid use leads to improved cognitive function, this may have implications for preventive strategies to reduce age-related cognitive decline in older individuals.

Methods

Participants

Participants were recruited from the Ear, Nose, and Throat Department of the University Hospital Maastricht and from the Health Centre Neerbeek, the Netherlands. All recruited participants were diagnosed with sensorineural hearing loss, i.e. an average pure-tone auditory threshold of 35dB or more for the best ear measured at 1, 2 and 4 KHz (Davis, 1995). Participants in the intervention group were fitted with hearing aids, whereas participants in the control group refrained from hearing aid use. Inclusion criteria were age 60 years or older, a minimum score of 24 on the Mini-Mental Status Examination, sufficient comprehension of the Dutch language, and no previous participation in a neuropsychological research programme. Exclusion criteria were documented evidence of neurological diseases of the central nervous system (e.g. dementia, Parkinson's disease) and a major psychiatric disorder. The local medical ethics committee approved the study and all participants gave their informed consent.

Auditory acuity

Calibrated standard audiometers with standard earphones were used in this study. A calibrated portable screening audiometer (Interacoustics AS7, Denmark) in a quiet room was used for threshold testing. Participants with hearing aids were assessed using free field audiometry in an audiometric booth at the Department of Audiology of the Maastricht University Hospital. The test protocol was identical for all participants. Pure-tone auditory thresholds were determined for each ear at six frequencies (0.25, 0.50, 1, 2, 4, and 8 KHz) always starting with the right ear. The auditory threshold for each frequency was fixed at the level at which the participant could detect the tone in two out of three presentation trials. Hearing thresholds are expressed in decibel units and tones were administered using a stepwise procedure (-10, +5 dB steps). Participants who were unable to identify a tone at 90dB were assigned the maximum score of 90 for that tone. Overall hearing acuity is expressed as the average of hearing thresholds at 1, 2 and 4 KHz for the best ear, according to recommendations for the assessment of hearing handicap (Davis, 1995).

Cognitive measures

Since hearing deficits and general cognitive performance, such as perceptual speed, reasoning, memory, knowledge, and verbal fluency, were earlier found to be associated (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994, 1997), a broad range of cognitive tests was administered to assess perceptual speed, speed of information processing, cognitive flexibility, memory, and verbal fluency.

The Stroop Colour-Word Test (SCWT) is a measure of selective attention and speed of information processing. This test involves three cards displaying forty stimuli each (Houx & Jolles, 1993; Stroop, 1935). The first card displays colour words printed in black ink, which have to be read aloud by the participant. The second card displays coloured patches, which have to be named. The last card displays colour names printed in incongruously coloured ink. Participants are instructed to name the ink colour of the printed words. By subtracting the time needed for the last part from the mean score for the first and second parts (SCWT-12), an interference score can be calculated (SCWT-i). This interference score is a measure of inhibition of a habitual response, which is considered to draw on the domain of executive functioning.

The Concept Shifting Task (CST; (Vink & Jolles, 1985) is a modified version of the Trial Making Test and is used as an instrument to measure simple cognitive speed and cognitive flexibility. It consists of three parts. On each test sheet, 16 small circles are grouped in a larger circle. The smaller circles contain numbers, letters, or both, appearing in a fixed random order. Participants are instructed to cross out the items in the right order. In the last part, participants have to alternate between numbers (1-8) and letters (A-H). The scores correspond to the time needed to complete each trial. The difference between the last part and the mean score of the first and second parts (CST-ab) is considered to reflect the additional time needed to shift between both sets of stimuli (CST-i).

The Letter-Digit Substitution Test (LDST) measures general information processing speed. This test is a modified version of the Symbol Digit Modalities Test (Lezak, 1995; Smith, 1968). A code is presented at the top of a page, in which a digit is linked to a letter. Participants have to fill in blank squares that correspond to the correct code. The dependent variable is the number of letters filled in correctly in 90 seconds.

Intentional learning and verbal memory functioning were measured using the Visual Verbal Learning Test (VVLT). In this test, 15 monosyllabic words are sequentially presented visually with an inter-stimulus-interval of 2 seconds. Participants are asked to recall as many words as possible. This procedure is repeated five times (Brand & Jolles, 1985). Because of an observed ceiling effect in the last two trials, the total score of the first three trails is used as dependent variable. After 20 minutes, participants are asked to reproduce the learned words again, as an estimate of delayed recall.

In the Verbal Fluency Test (Lezak, 1995) participants are asked to produce as many words as possible in a given category (animals) in 60 seconds. The variables of interest are the number of correctly named animals. The score can be seen as a measure of adequate, strategy-driven retrieval of information from semantic memory.

Other variables

Four subtasks of the Groningen Intelligence Test (GIT) were used to estimate IQ (Luteijn & van der Ploeg, 1983). The four subtasks involved were: the correct completion of as many addition sums as possible in 1 minute; indicating which of five alternative words is synonymous with a given word; indicating which two-dimensional shape from a larger set is needed to exactly fill up a given space; and indicating which of five alternatives is related in the same way to a given word as two words in an example.

Level of education was indexed on an 8-point ordinal scale: 1=primary education, 2=lower vocational education, 3=intermediate general secondary education, 4= intermediate vocational education, 5=higher general secondary education/ university preparatory education, 6=higher vocational preparatory education, 7=higher professional education, 8=university education (De Bie, 1987).

Procedure

The study had a dual baseline, controlled design. Participants were not randomly assigned to groups because this was ethically unfeasible. For this reason, the control group consisted of participants with an objective hearing impairment but who did not volunteer for the use of hearing aids because they had less severe complaints about their hearing impairment, had no subjective hearing handicap, or considered a hearing aid too expensive (in the Netherlands, health insurance covers only part of the cost of a hearing aid and only if the impairment is at least 35 dB, averaged across 1,2, and 4 kHz for the best ear). Participants in the intervention group had never used a hearing aid previously. All participants were tested on three occasions. First, a dual baseline measurement was performed in order to reduce the possible effects of (procedural) learning. The mean interval between the first and second assessments was 13 days. The second baseline measurement was taken as the reference performance level before intervention. Next, participants in the intervention group were fitted with hearing aids. The mean interval between the second baseline measurement and fitting of hearing aids was10 days (SD=53.2). All participants were re-tested after 12 months, counted from the moment of the first baseline assessment. The neuropsychological tests were administered in the same order on all test occasions. Since learning effects may occur in the Visual Verbal Memory Test, parallel versions were used (Hijman et al., 1992).

Statistical analysis

First, differences in demographic variables (i.e. age, educational level, and intelligence) and hearing ability between both groups were compared using Student t-tests. A Chi-square test was used to analyse group differences with respect to sex. In order to examine the effect of hearing aid use on auditory acuity and cognitive functioning, the performance of the intervention and control groups at follow-up was compared using an Analysis of Variance (ANOVA), with adjustment for the baseline score. In addition, when analysing the effect of hearing aids use on cognitive function, age, sex, and educational level were treated as covariates, because these variables are established factors that may directly affect cognitive functioning. All analyses were performed on an 'intention to treat' basis, i.e. the original group assignment was kept fixed at the start of the trial (Altman et al., 2001). Furthermore, additional analyses were performed for those individuals in the intervention group who used their hearing aid at least 8 hours a day. They were compared with the control participants who still chose not to use a hearing prosthesis after assignment to the control group (compliance analysis). All analyses were performed using the SPSS for Macintosh program series, version 10 (SPSS-Inc., Chicago), with p=0.05 as significance level.

Results

Recruitment

Two hundred and ten individuals were screened for participation in this study (Figure 1). Of the 124 adults who were to receive a hearing aid, 49 refused to participate in the study and 4 did not meet the inclusion criteria (MMSE score <24).

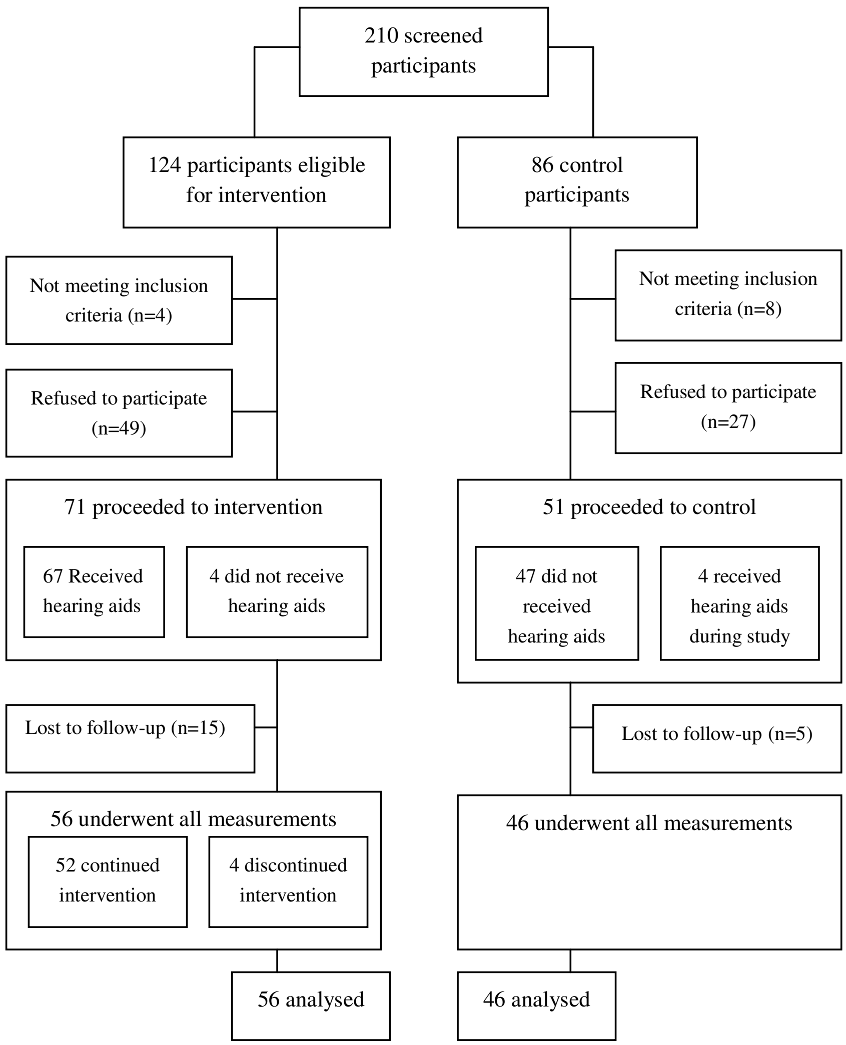

Figure 1. Flowchart of the participants

Four individuals in the intervention group postponed using hearing aids and 15 people (21%) did not complete all measurements. Main reasons for dropout were lack of interest (n=8), illness (n=2), and other or unspecified reasons (n=5). The control group consisted of 86 individuals who did not want to use hearing aids. Of these people, 27 refused to participate and 8 were excluded (MMSE score <24). During the study period, however, four individuals in the control group decided to start using hearing aids; their data were included in the statistical analysis because of the 'intention to treat' notion. Five control people (i.e. 10%) did not complete the study due to lack of interest (n=2), illness (n=1), or unspecified reasons (n=1); 1 participant died. The number of dropouts was not significantly higher in the intervention group (Chi-square=2.78; p=0.10). Finally, 102 participants completed all assessments (i.e. 56 experimental, 46 control).

Baseline characteristics

There were no significant differences between the intervention group and the control group with respect to age (t(1,101)=-1.40, p=0.17), sex (Chi-square(1,131)=0.02, p=0.90), educational level (t(1,101)=-0.03, p=0.97), intelligence level (t(1,101)=1.09, p=0.28), or hearing threshold (t(1,101)=1.59, p=0.12; see Table 1).

Table 1. Means and standard deviations of demographic variables and hearing acuity in both study groups

	Intervention	Control	p-value
N	56	46	
Age	72.5 (7.3)	74.5 (6.8)	0.17
Education	3.2 (2.0)	3.2 (2.1)	0.97
Sex (% men)	64%	63%	0.90
Intelligence	117.7 (14.0)	114.5 (14.8)	0.28
Hearing threshold	46.5 (7.3)	44.1 (7.7)	0.12

Note: Student's t-tests were used to test differences in age, education, intelligence, and hearing threshold. Sex differences were analysed using Chi-square test.

Effects of hearing aid use

One year after the start of the study, the intervention group had better aided auditory thresholds than the unaided control group (F(1,92)=12.16, p<0.01); however hearing aid use did not improve cognitive performance (for all tests: F(1,92)<1.54, p>0.22; see Table 2). Unexpectedly, the intervention group had a poorer performance on SCWT I/II than the control group 1 year after the hearing aids were fitted (F(1,92)=5.51, p<0.05).

An essentially similar pattern of results was seen in the mixed design ANOVAs with one between-subjects factor (intervention/control) and one within subjects factor (baseline/follow-up). Additional analyses were performed to compare control participants who did not take hearing aids within the study period (n=42) with participants in the intervention group who used their hearing aid at least 8 hours per day (n=31). These analyses again revealed that there was no differential improvement in cognitive performance in hearing aid users (for all tests: $F(1,72)<3.44$, $p>0.07$; results not tabulated).

Table 2. Means, standard deviations (SD), standard errors (SE), and results of tests for group differences of the objective test performances.

	Unadjusted		Adjusted [a]		
	Baseline	1-year follow-up	1-year follow-up	F-value	p-value
	Mean (SD)	Mean (SD)	Mean (SE)		
SCWT I/II [b]				5.51	0.02
Intervention	21.81 (5.17)	22.87 (5.78)	22.78 (0.28)		
Control	21.70 (4.61)	21.69 (3.61)	21.80 (0.31)		
SCWT I [b]				0.15	0.70
Intervention	30.58 (14.02)	35.51 (24.43)	37.22 (2.55)		
Control	38.21 (25.00)	37.88 (16.87)	35.75 (2.85)		
CST ab [b]				0.09	0.76
Intervention	28.83 (8.83)	28.70 (9.79)	29.08 (0.77)		
Control	29.75 (8.81)	29.91 (8.27)	29.43 (0.86)		
CST I [b]				1.45	0.23
Intervention	20.42 (17.40)	22.07 (17.55)	21.88 (2.07)		
Control	17.23 (17.75)	17.86 (19.42)	18.10 (2.31)		
VVLT immediate recall				0.16	0.69
Intervention	22.89 (5.97)	25.50 (5.63)	25.61 (0.52)		
Control	23.59 (4.76)	24.96 (5.85)	25.30 (0.59)		
VVLT delayed recall				0.73	0.40
Intervention	9.64 (3.19)	10.09 (2.91)	9.75 (0.29)		
Control	8.31 (2.98)	9.47 (3.44)	10.13 (0.33)		
LDMT				0.91	0.34
Intervention	27.34 (6.71)	26.32 (6.82)	25.84 (0.44)		
Control	26.22 (7.87)	24.60 (7.65)	25.20 (0.50)		
Verbal Fluency				1.54	0.22
Intervention	27.30 (6.63)	25.18 (6.87)	24.89 (0.70)		
Control	26.72 (6.30)	23.22 (6.32)	23.58 (0.79)		

SCWT= Stroop Colour Word Test; CST = Concept Shifting Task; LDST = Letter Digit Substitution Test; VVLT= Visual Verbal Learning Test.

[a] Follow-up group differences were analysed using Analysis of Variance, adjusted for baseline score, age, sex, and educational level

[b] Higher scores reflect poorer performance

Discussion

The aim of the present study was to examine the effects of hearing aid use by older adults on a broad range of cognitive functions, including information processing speed, memory, and verbal fluency. Aided hearing acuity improved after intervention compared to participants who did not receive hearing aids. However, hearing aid use did not affect cognitive performance in older adults over a 12-month episode. It thus appears that hearing aid use only compensates for impairments at the level of the sensory input system but does not contribute to an improvement in the efficiency of information processing mechanisms at the level of the central nervous system.

The findings of Mulrow et al. (1990), that hearing aid use had beneficial effects on global cognitive functioning may be explained by the fact that the Short Portable Mental Status Test used in that study to measure global cognitive functioning contains ten questions that are presented in an auditory mode. Hearing-impaired individuals may be less able to identify auditory information and therefore perform worse than individuals who use hearing aids. This is also in line with earlier findings from Van Boxtel et al. (2000) who found a direct relationship between the degree of hearing loss and verbal memory when auditory stimuli were used. The tests used both in our study and in the study of Tesch-Römer (1997) were presented visually, and the findings from both studies indicated that hearing aid use had no effect on cognitive functions. Therefore, it seems that the difference in presentation mode between these studies might explain the inconsistent findings.

Theoretically, it remains possible that the effects of hearing aid use appear only after a period longer than twelve months. The sensory deprivation hypothesis expects that the absence of stimulation of a particular sensory system over a longer period of time limits communication and may thus affect cognitive functioning. The amount of time needed for cognitive improvement to become apparent is ,however, unspecified, and may be more than the time frame that was chosen for the present study. This issue may be addressed in future studies in which the change in cognitive performance is followed over a longer period of time, perhaps even years.

Several aspects should be considered when interpreting these results. First, the low correlations between cognitive measures and sensory functioning are not in line with the findings of previous studies. Studies that have demonstrated substantial associations between cognitive measures and auditory and visual functioning included a study population with a much larger variability in sensory acuity (Valentijn et al., accepted). The range of hearing thresholds in the present study was restricted, since our study population only included participants with mild to severe hearing loss. This 'restriction of range' may have caused the correlations between hearing threshold levels and cognitive measures to remain below the significant level. Second, as mentioned above, while a randomized, controlled trial would be the best option to overcome any potential pre-existing between-group differences, it was considered unethical to stop or delay the use of a hearing aid by persons who need one, which forced us to use the present design. Therefore, the conclusions from this study are drawn on the assumption that the intervention group and the control group did not differ substantially at baseline in terms of variables that may have affected the outcome of the study. The participants of the intervention group expressed complaints about their hearing and applied for hearing aids, whereas the participants in the control group, who may also have experienced difficulties in hearing, did not consider the use of a hearing aid. Although these group differences could be explained by different coping styles, this was considered less likely because the general tendency to complain, measured by the neuroticism scale of the Eysenck personality scale (Eysenck, Eysenck, & Barrett, 1985), was not more pronounced in the intervention group ($F(1,95)=0.87$; $p=0.35$). A third point concerns the control group's better performance after 1 year on the simple speed measure of the Stroop Colour-Word Test. This subtle difference disappeared in the additional analyses comparing a compliant group of participants (i.e. participants who used their hearing aid at least 8 hours a day) with control participants who did not use hearing aids). We had no expectation of such effect and consider this finding most likely to be due to a type I error.

In conclusion, although hearing aid use is a proven successful intervention to alleviate age related hearing loss, the impact of using hearing aids would probably have no major implications for cognitive mechanisms mediated by the central nervous system in older healthy adults. The clinical observation that hearing-impaired individuals who use hearing aids may have experience an improved cognitive functioning if information is presented in the auditory mode, may simply be due to better perceiving and interpreting the auditory information.

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Chapter 8

Hearing-specific and generic effects of hearing aid use in older adults: A controlled intervention study

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Abstract

The aim of this study was to investigate, in hearing-impaired older adults, the effects of hearing aid use on hearing-specific and general quality of life measures that have been adversely associated with hearing impairment over a period of 12 months. Participants who were fitted with hearing aids for the first time were compared with control participants with an equivalent hearing impairment, but who were not fitted with hearing aids. After a baseline measurement and fitting of the hearing aids, all participants filled in questionnaires on quality of life (EuroQol and SF-36), depressive symptomatology (depression subscale of SCL-90) and subjective auditory ability (ADPI) at both 6 and 12 months. Analysis of variance revealed that hearing thresholds improved after hearing aid use. Both at 6 and 12 months, hearing aids improved subjective auditory ability. However, in the intention to treat analysis, hearing aid use did not have positive effects on general quality of life measures. Still, a subgroup of hearing aid users who experienced improved subjective auditory functioning reported better physical and social functioning, fewer physical problems, a better mental health, and more vitality after hearing aid use compared with the control group. The use of hearing aids in older adults seems helpful in improving both objective and subjective auditory functioning. People who felt they heard better with a hearing aid also experience a general improvement in quality of life measures.

Introduction

More than one-third of people older than 60 years have a hearing impairment (Tesch-Romer, 1997). Hearing impairment in old age, also known as presbyacusis, is characterised by a gradual decrease in hearing, particularly in the higher frequencies that are relevant for understanding speech (Kline & Scialfa, 1996). Not only communication problems may arise (Fook, Morgan, Sharma, Adekoke, & Turnbull, 2000), presbyacusis may also adversely affect well-being, quality of life (Bess, 2000), (instrumental) activities of daily life (Carabellese et al., 1993; Strawbridge, Wallhagen, Shema, & Kaplan, 2000; Wallhagen, Strawbridge, Shema, Kurata, & Kaplan, 2001), social (Mulrow, Aguilar, Endicott, Velez et al., 1990), physical (Reuben, Mui, Damesyn, Moore, & Greendale, 1999), and psychological functioning, such as depressive symptoms (Cacciatore et al., 1999; Naramura et al., 1999; Pope & Sowers, 2000; Scherer & Frisina, 1998). In the present study, we investigated the extent to which hearing-impaired older adults benefit from rehabilitation with hearing aids in terms of hearing specific functioning and functions known to be related to hearing impairments.

In the past decades, several studies have investigated the effect of hearing aid use in older adults, both on disease-specific and generic measures of functioning (Appollonio, Carabellese, Frattola, & Trabucchi, 1996; Bess, 2000; Joore, Brunenberg, Chenault, & Anteunis, 2003; Mulrow, Aguilar, Endicott, Tuley et al., 1990; Tesch-Romer, 1997; Weinstein, 1996). However, few of these studies have evaluated these effects using a controlled study design (Mulrow, Aguilar, Endicott, Tuley et al., 1990; Tesch-Romer, 1997). The randomised controlled study of Mulrow et al. (1990) investigated adults aged 64 years and older. People who were fitted with hearing aids (n=95) showed significant improvements in specific hearing-related measures, depressive symptoms, and general cognitive functioning 6 months later, compared with people in the waiting list control group (n=99); however, no significant changes were found on a generic functional health status measure. Because most participants were male veterans, the results of Mulrow et al. (1990) may not be generelizable to other populations. In another controlled intervention study, Tesch-Romer (1997) detected positive effects of hearing aid use in 140 older adults (between 51 and 87 years old) on disease-specific measures after 6 months, but no effects in general domains, such as social activities, satisfaction with social relations, well-being, and cognitive functioning. Thus, the controlled studies performed so far have demonstrated that hearing aid use may have positive effects on hearing-specific aspects after 6 months. However, there seems to be no consensus whether hearing aid use may affect other domains of functioning, such as mood and social functioning, or more general domains of functioning, such as well-being or quality of life.

The studies of Mulrow et al. (1990) and Tesch-Romer (1995) examined the effects of hearing aid use 6 months after the fitting of the prosthesis, which is approximately the period needed for individuals to get fully accustomed to using hearing aids (Henrichsen, Noring, Lindemann, Christensen, & Parving, 1991). It is therefore possible that the effects of hearing aid use on more generic measure were not detected after the relatively brief episode of 6 months, since it may be expected that generic effects of hearing aid use will emerge only when persons are accustomed to the use of their hearing aid for a longer period. To our knowledge, no study has systematically investigated the long-term effects of hearing aid use on hearing specific and general quality of life measures.

In the present controlled intervention study, we investigated whether hearing aid use improved hearing specific aspects and measures reported to be adversely influenced by hearing impairment (i.e. quality of life, depressive symptoms, physical functioning, social functioning, and hearing specific quality of life) in adults older than 60 years who were fitted with hearing aids for the first time. This study extended previous studies in that the effects of hearing aid use were examined at both medium (6 months) and long-term (12 months) follow-up occasions. Based on the studies mentioned above, we expected that hearing aid use would improve hearing-related measures, but would have only a limited impact on the generic measures.

Improvement of auditory functioning with hearing aids in older adults is often difficult to accomplish. Hearing aids not only amplify important low-intensity information, but also unwanted background or competing sounds and thus hearing aids do not yet offer sufficiently sophisticated signal processing to mimic the processing performed by an intact auditory system (Schneider & Pichora-Fuller, 2000). About a third of older hearing-aid users experience difficulties in everyday situations due to multiple signals or background noise (Schneider & Pichora-Fuller, 2000). In order to adjust for these difficulties, we also performed an additional analysis restricted to those participants in the intervention group who clearly experienced a subjective improvement in hearing. These participants were compared with a control group that did not receive hearing aids.

Methods

Participants

Participants were recruited from the Ear, Nose and Throat Department of the University Hospital Maastricht and from the Health Centre Neerbeek, the Netherlands. All recruited participants were diagnosed with sensorineural hearing loss, i.e. an average pure-tone auditory threshold of 35dB or more at the best ear, measured at 1, 2 and 4 KHz (Davis, 1995). The intervention group received hearing aids, while participants in the control group did not. Other inclusion criteria were age (60 years or older), a score of at least 24 on the Mini-Mental State Examination (MMSE), and sufficient comprehension of the Dutch language in order to understand testinstructions. Exclusion criteria were evidence of neurological diseases of the central nervous system (e.g. dementia, Parkinson's disease) or a major psychiatric disorder. The local medical ethics committee approved the study and all participants gave their informed consent.

Auditory acuity

A calibrated portable screening audiometer (Interacoustics AS7, Denmark) was used in a quiet room for pure tone threshold testing. Participants fitted with hearing aids were assessed by free field audiometry inside an audiometric booth at the Department of Audiology of the Maastricht University Hospital. Testing started at the right ear. Pure-tone auditory thresholds were determined for each ear at six frequencies: 0.25, 0.50, 1, 2, 4, and 8 KHz. The auditory threshold for each frequency was fixed at the level where the participant could detect the tone in two out of three presentation trials. Hearing thresholds were expressed in decibel units with 5 dB accuracy on a scale ranging from -15 (good hearing ability) to 90 dB (poor hearing ability). Participants who were unable to detect tones at 90dB received the maximum score of 90. The overall hearing acuity was expressed as the average of hearing thresholds at 1, 2, and 4 KHz for the better ear, according to recommendations for the assessment of hearing handicap (Davis, 1995).

Questionnaires

Questionnaires were administered to examine variables, which were correlated with impaired auditory functioning in previous studies, i.e. hearing specific and quality of life (including physical and social functioning), and depressive symptoms. Selection of questionnaires was based on use in earlier studies and adequate reliability.

Quality of life

Overall quality of life was measured with the EuroQol, which is a widely accepted questionnaire to measure generic health-related quality of life (Group, 1990). The EuroQol includes a single visual analogue scale, presented as a “feeling thermometer”, with which individuals rate their own health-related quality of life. The EuroQol is suitable for use in older populations. The scores range from 0 (lowest level of health-related quality of life) to 100 (highest level).

Specific domains of quality of life were assessed with the SF-36 questionnaire (Ware & Sherbourne, 1992). The SF-36 is coded into eight scales: physical functioning, social functioning, role limitations due to physical problems, role limitations due to emotional problems, general mental health, vitality, bodily pain, and general health perceptions. Each scale is scored from 0 (lowest level of functioning) to 100 (highest level).

Depressive symptoms

Depressive symptoms were scored using the subscale of the Symptom-Check-List 90 (SCL-90). The SCL-90 is a widely used multidimensional checklist for psychopathological complaints (Arrindell & Ettema, 1986; Derogatis, 1977). The theoretical score for depression ranges from 0 (no symptoms) to 80 (maximum).

Hearing specific quality of life

The Audiological Disabilities Preference Index (ADPI) was included to measure subjective auditory ability (Joore et al., 2002). This questionnaire is based on the Amsterdam Inventory (Kramer, Kapteyn, Festen, & Tobi, 1995). The ADPI can identify different dimensions of hearing disability and handicap, which were based on a factor analysis. The questionnaire consists of a total of five items related to the detection of sounds, intelligibility of speech in quiet environments, intelligibility of speech in noisy surroundings, auditory localisation, and distinction of sounds. Each question has three possible answers: severe problems (1), moderate problems (2), and no problems (3). In addition, respondents rated their own level of subjective hearing disability on a visual analogue scale, ranging from deaf (0) to perfect hearing (100).

Procedure

This controlled intervention study recorded measurements at baseline and at 6 and 12 months. Random assignment of the hearing-impaired participants to the intervention group and the control group was deemed impossible for ethical reasons. In addition, a waiting list control design was considered unfeasible for the same reason, because available medical care cannot be withhold to patients with a diagnose. In addition, it was concluded that a waiting list control group may result in substantial bias, due to attrition or non-compliance. Therefore, the control group consisted of age and sex-matched participants with an objective hearing disorder, but who did not volunteer for the use of hearing aids because they had few complaints about hearing impairment, no subjective hearing handicap, or found a hearing aid too expensive. All participants had no prior experience with the use of a hearing aid. After a baseline measurement, the participants in the intervention group received hearing aids adjusted to their personal needs (mean interval after baseline measurement was 10 days). Participants in the intervention group received routine instructions on the use, care, and function of the hearing aid. The first follow-up measurement was scheduled 6 months after the baseline measurement, which is approximately the period needed for individuals to get fully accustomed to the use of a hearing aid (Henrichsen et al., 1991). Twelve months after the first measurement, a second follow-up measurement was scheduled. Auditory acuity was measured at baseline and 12 months, whereas the questionnaires were administered at baseline and 6 and 12 months.

Statistical analysis

First, differences in demographic variables (i.e. age and educational level) and hearing ability between groups were compared using Student *t*-tests. A Chi-sqaure test was used to analyse group differences with respect to sex. General Linear Model (GLM) repeated measures analysis of variance was used to investigate the effects of hearing aid use on quality of life, depressive symptoms, and hearing specific quality of life. Analyses were performed with group (intervention yes/no) as between-subject factor, and time (first and second follow-up) as within-subject factor. Baseline scores were treated as covariates in this model, in order to control for any pre-existing group differences. Since auditory acuity was measured at baseline and follow-up only, Analysis of Variance (ANOVA), adjusted for baseline score, was used to compare auditory acuity at 12 months between the intervention group and the control group. The scores of the five questions of the ADPI did not meet the assumptions for GLM, since these consisted of three answer categories. For these five variables, change scores (from baseline to follow-up) were calculated and were analysed using nonparametric Mann-Whitney U-tests. All analyses were performed according to the 'intention to treat' principle, i.e. group assignment at the start of the trial was kept fixed in the statistical procedure (Altman et al., 2001). Furthermore, additional ‘on treatment’ comparisons were performed using data from participants in the intervention group who reported improved hearing functioning on the visual analogue scale of the ADPI at follow-up, compared to baseline. These participants of the intervention group were compared with the control group. All analyses were performed using the SPSS for Macintosh program series, version 10 (SPSS Inc., Chicago), with $p=0.05$ as significance level.

Results

Recruitment

Two hundred and ten individuals were screened for this study (Figure 1 of Chapter 7). Of the 124 adults who were to receive a hearing aid, 49 refused to participate in the study, and 4 individuals did not meet the inclusion criteria (MMSE<24). After inclusion, four individuals wanted to delay hearing aid use. According to Altman et al. (2001) [28], these participants were included in the intention to treat analyses, just like the four participants who discontinued the intervention. Fifteen individuals in the intervention group did not complete all assessments in the study and were treated as dropouts. Main reasons for dropping out were a lack of interest (n=8), illness (n=2) or other, unspecified reasons (n =5).

The control group consisted of 86 individuals who did not choose to receive a hearing aid at study inclusion. Of those individuals, 27 refused to participate in the study and 8 scored below the cut-off of the MMSE. Five persons did not complete the study, due to a lack of interest (n =2), illness (n =1), or unspecified reasons (n =1), and one participant died. The number of dropouts was not significantly higher in the intervention group (Chi-sqaure=2.78; p=0.10). Finally, 102 participants completed all assessments (i.e. 56 intervention, 46 control). Post hoc power analysis on the available number of participants using a medium critical effect size of 0.15 and an alpha level of 0.05 resulted in a power of 0.97 for this study (Buchner, Faul, & Erdfelder, 1992).

Baseline characteristics

There were no significant differences between the intervention group and the control group with respect to age (t(1,101)=-1.40, p=0.17), sex (Chi-square(1,101)=0.02, p=0.90), educational level (t(1,101)=-.03, p=0.97), and hearing thresholds (t(1,101)=1.59, p=0.12)

Table 1. Means and standard deviations of demographic variables and hearing acuity in both study groups.

	Intervention	Control	p-value
N	56	46	
Age	72.5 (7.3)	74.5 (6.8)	0.17
Education	3.2 (2.0)	3.2 (2.1)	0.97
Sex (% men)	64%	63%	0.90
Intelligence	117.7 (14.0)	114.5 (14.8)	0.28
Hearing threshold	46.5 (7.3)	44.1 (7.7)	0.12

Note: Student's t-tests were used to test differences in age, education, intelligence, and hearing threshold. Sex differences were analysed using Chi-square test.

Effects of hearing aid use (according to 'intention to treat')

Auditory thresholds

One year after receiving the hearing aids, the aided intervention group had better auditory thresholds than the unaided control group ($F(1,92)=12.16$, $p<0.01$).

Table 2. Adjusted means and standard error of the mean (SEM) of quality of life measures and the depressive symptomatology scale.

	6-month follow-up	1-year follow-up	Main intervention effect	Interaction effect
	Mean (SEM)	Mean (SEM)	p-value	p-value
Quality of life				
EuroQol				
Intervention	73.52 (1.62)	74.18 (1.52)	0.80	0.68
Control	73.53 (1.78)	73.17 (1.66)		
SF-36				
Physical functioning				
Intervention	71.61(2.32)	73.05 (2.11)	0.41	0.59
Control	68.37 (2.57)	71.48 (2.34)		
Social functioning				
Intervention	82.05 (2.54)	81.32 (2.39)	0.38	0.86
Control	79.54 (2.84)	82.72 (2.68)		
Physical problems				
Intervention	74.99 (4.44)	74.19 (4.95)	0.21	0.34
Control	72.04 (5.00)	62.93 (5.57)		
Emotional problems				
Intervention	82.16 (4.38)	79.72 (4.76)	0.51	0.63
Control	80.49 (4.82)	74.14 (5.23)		
Mental health				
Intervention	76.32 (1.51)	77.31 (1.64)	0.63	0.22
Control	76.98 (1.68)	74.75 (1.82)		
Vitality				
Intervention	67.85 (1.93)	64.71 (1.94)	0.99	0.44
Control	66.62 (2.14)	65.93 (2.15)		
Pain				
Intervention	73.84 (2.65)	78.39 (2.79)	0.81	0.24
Control	75.60 (2.96)	74.97 (3.12)		
General health				
Intervention	63.57 (1.70)	59.76 (1.84)	0.52	0.12
Control	63.04 (1.89)	63.32 (2.04)		
SCL-depression				
Intervention	22.62 (0.86)	24.32 (0.81)	0.48	0.55
Control	22.21 (0.94)	23.19 (0.89)		

Note: Group differences were analysed using general linear model with repeated measure analysis, adjusted for baseline score.

Overall health-related quality of life

After fitting hearing aids, the score on the EuroQol and the subscale scores of the SF-36 did not differ between the intervention group and the control group (see Table 2). The interaction effects were also not significant, indicating that findings were similar for the medium and long-term follow-up evaluations.

Depressive symptoms

Hearing aid use did not affect the score on the SCL-depression scale (F(1,94)=0.50; p=0.48; see Table 2). In addition, there was no interaction between group and time, indicating that the scores on the SCL-depression did not change after the first follow-up investigation (F(1,94)= 0.36; p=0.55).

Table 3. Mean and standard deviations of the Audiological Disabilities Preference Index

	Baseline	6-months follow-up	1-year follow-up	Short term effect	Long term effect
	Mean (SD)	Mean (SD)	Mean (SD)	p-value	p-value
Detection of sounds					
Intervention	2.27 (.65)	2.60 (.56)	2.70 (.50)	0.02	<0.01
Control	2.44 (.62)	2.47 (.63)	2.48 (.66)		
Intelligibility in quiet					
Intervention	2.27 (.65)	2.49 (.63)	2.66 (.48)	<0.01	0.02
Control	2.42 (.58)	2.36 (.57)	2.48 (.55)		
Intelligibility in noise					
Intervention	2.07 (.66)	2.25 (.64)	2.30 (.66)	0.14	0.19
Control	2.44 (.62)	2.47 (.63)	2.51 (.59)		
Auditory localisation					
Intervention	2.36 (.56)	2.57 (.54)	2.61 (.49)	0.23	0.04
Control	2.60 (.54)	2.68 (.52)	2.59 (.54)		
Distinction of sounds					
Intervention	2.60 (.56)	2.73 (.49)	2.77 (.43)	0.34	0.08
Control	2.73 (.58)	2.80 (.46)	2.72 (.50)		

Note: Group differences were analysed using Mann-Whitney *U* test.

Hearingspecific quality of life

Means and standard deviations of hearing specific quality of life are presented in Table 3. At 6 months follow-up, the intervention group was better able to detect sounds (z=-2.29; p=0.02) and to understand speech in a quiet environment (z=-2.80; p=0.01) than were control participants. This improvement was also present at 1 year follow-up (z=-3.30; p<0.01 and z=-2.44; p=0.02, respectively). However, hearing aid use did not significantly improve other aspects of hearing specific quality of life, i.e. intelligibility of speech in noisy surroundings, auditory localisation, and distinction of sound. In addition, hearing ability, as measured with the visual analogue scale of the ADPI, was not significantly improved in the intervention group compared to the control group (main intervention effect: F(1,94)=1.77; p=0.19; interaction effect: F(1,94)=0.03; p=0.87, see Table 4), albeit the effects were in the expected direction, i.e. the mean scores of the intervention group did improve.

Table 4. Adjusted means and standard error of the mean (SEM) of visual analogue scale of the Audiological Disabilities Preference Index

	6-months follow-up	1-year follow-up	Main intervention effect	Interaction effect
	Mean (SEM)	Mean (SEM)	p-value	p-value
Intervention	67.02 (2.27)	68.10 (2.42)	0.19	0.87
Control	63.42 (2.56)	63.84 (2.73)		

Note: Group differences were analysed using GLM with repeated measure analysis, adjusted for baseline score.

Effects of hearing aid use ('on-treatment' comparisons)

In the on-treatment comparisons (not tabulated), those participants from the intervention group who reported better hearing functioning on the visual analogue scale of the ADPI at follow-up, compared to baseline (n=30), were compared with participants from the control group (n=46). These groups did not differ on baseline characteristics, i.e. age (t(1,75)=-1.13, p=0.26), education (t(1,75)=0.12, p=0.90), sex (X^2(1,75)<0.01, p=0.98), and hearing threshold (t(1,75)=1.11, p=0.27).

Quality of life

The main effect and the interaction effect on the EuroQol were not significant (F(1,71)=1.30, p=0.26 and F(1,71)=0.15, p=0.70, respectively), indicating that overall quality of life was not better in the participants who were positive about hearing ability after hearing aid use than in the control participants. However, the restricted intervention group improved significantly compared to the control group after use of hearing aids on physical functioning (F(1,70)=6.83, p=0.01), social functioning (F(1,71)=8.05, p<0.01), physical problems (F(1,68)=6.40, p=0.01), mental health (F(1,70)=6.54, p=0.01), and vitality (F(1,70)=9.77, p<0.01). The interaction effects on these SF-36 scales were not significant, indicating that the difference in scores at 6 months follow-up and at 1-year follow-up did not change. Post hoc univariate ANOVA using data for the 12 month assessment with adjustment for the baseline score also showed hearing aid use to have a significant beneficial effect on physical functioning ($F(1,69)=6.82$, $p=0.01$).

Depressive symptoms

The intervention did not influence the score of the SCL-depression since the main effect was not significant ($F(1,71)=0.25$, $p=0.62$). The interaction effect was not significant either ($F(1,71)=1.05$, $p=0.31$), indicating that the score of the two groups did not differ between the first and second follow-up measurement.

Hearing specific quality of life

After the restricted intervention group started using hearing aids, nearly all items of the ADPI improved compared to the control group participants. They detected sounds significantly better at both the 6-month ($z=-3.57$, $p<0.01$) and the 12-month ($z=-4.21$, $p<0.01$) follow-up evaluations. Intelligibility of speech in quiet environments and distinction of sounds was also significantly improved in the intervention group compared to the control group, both on the 6-month ($z=-2.97$, $p<0.01$ and $z=-2.22$, $p=0.03$) and the 12-month ($z=-3.03$, $p<0.01$ and $z=-2.06$, $p=0.04$) follow-up evaluations. Intelligibility of speech in noisy surroundings was better than that of controls at 6-month ($z=-2.17$, $p=0.03$) but this effect disappeared after 12 months ($z=-1.75$, $p=0.08$). Auditory localisation was better at 12 months in the restricted intervention group ($z=-2.05$, $p=0.04$), but not at 6 months ($z=-1.84$, $p=0.07$).

Discussion

The purpose of this study was to test whether hearing aid use had a positive effect solely on hearing-specific functioning or whether it had more general effects, such as on quality of life, physical and social functioning, and depressive symptomatology which have previously been reported to be affected by hearing impairments (Bess, 2000; Cacciatore et al., 1999; Carabellese et al., 1993; Mulrow, Aguilar, Endicott, Velez et al., 1990; Naramura et al., 1999; Pope & Sowers, 2000; Reuben et al., 1999; Scherer & Frisina, 1998; Strawbridge et al., 2000; Wallhagen et al., 2001). In our study, we found that hearing aid use improved aided hearing thresholds and had positive effects on hearing specific quality of life; at both 6 and 12 months after participants had started to use a hearing aid, their ability to hear sounds and to understand speech in a quiet environment had improved. However, their general functioning, in terms of quality of life, physical and social functioning, and depressive symptoms, was not better than that of the untreated control participants (with a comparable hearing impairment) at 6 and 12 months. Thus, generic effects of hearing aid use were not found when persons were expected to be accustomed to the use of their hearing aid (i.e. after 6 months), nor when they were thought to be accustomed to it for a longer while (i.e. after 12 months).

Since one third of older hearing aid users experience difficulties in situations where there are multiple signals or background noise (Schneider & Pichora-Fuller, 2000), additional anaylses were performed, comparing people who felt their hearing to have been improved by a hearing aid with participants from the control group. Not only was detection of sounds, intelligibility of speech in a quiet environment, distinction of sounds, and auditory localisation improved, but the hearing aid users also reported better physical and social functioning, fewer physical problems, a better mental health, and more vitality compared to the control group. Again, overall quality of life, emotional problems, pain, general health, and depressive symptomatology were not improved after hearing aid use. It is possible that these perceived positive effects of hearing aid use in this subgroup of participants reflected a general positive answer tendency, in that persons in the intervention group who reported improved auditory functioning with hearing aids may have answered all questionnaires in a positive manner after hearing aid use. However, since effects of hearing aid use in these on-treatment analyses were not found on all aspects of functioning, it seems less likely that a positive answer tendency alone could explain the beneficial effects of hearing aid use. Secondly, the people who experienced benefit from hearing aid use may have had a more impaired hearing threshold, could have been older, experienced more depressive symptomatology, or were higher educated than the persons who did not experience an improvement in hearing ability. However, this was not the case. Lastly, we did not control for specific hearing aid characteristics, which could explain part of the positive effects on general measures in a subgroup of the intervention group. For example, the use of linear, compression, and programmable hearing aids was found to improve signal audibility, speech recognition scores, and perceived hearing handicap in an earlier study (Newman & Sandridge, 1998).

Several methodological considerations should be made when interpreting these results. As mentioned earlier, while a randomized-controlled trial would best overcome any potential pre-existing between-group differences, it was considered unethical to stop or delay people from using a hearing aid, when medically indicated, and so we could not pursue this design. Therefore, the conclusions from this study are drawn under the assumption that the intervention group did not differ at baseline on variables that may affect the outcome of the study. The participants of the intervention group had complaints about auditory functioning, whereas the participants in the control group, who also may have experienced difficulties in auditory functioning, did not consider hearing aids necessary. Although a difference in coping style could be an explanation for the group differences, this was considered less likely because the general tendency to complain, measured with the neuroticism scale of the Eysenck personality scale (Eysenck, Eysenck, & Barrett, 1985), was not more pronounced in the intervention group ($F(1,95)=0.87$; $p=0.35$).

The implication of this study is that hearing aid use improves both objective and subjective hearing functioning. In people who experience a better auditory ability with hearing aids, the use of a hearing aid may also improve physical and social functioning, mental health, and vitality. It therefore seems likely that successful adaptation to a hearing device may facilitate the autonomy and well-being of older individuals.

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Concluding remarks

The first objective of this thesis was to investigate differences in cognitive performance between age groups and to explore some determinants of successful cognitive aging in a longitudinal follow-up study. The second objective was to examine the effects of specific interventions for older adults on cognitive functioning, well-being, and quality of life. There was special emphasis on executive functioning, and a large cross-sectional-longitudinal study of cognitive aging was used as the basis for the research described in earlier chapters. A major goal was, to obtain more information about the concept of 'Successful *Cognitive* Aging'. A large sample of older participants from the Maastricht Aging Study was used to evaluate the following topics: the nature of cognitive differences between older age groups, the biological and psychosocial determinants of age-related cognitive decline, the influence of a high level of functioning on cognition, and the relation between cognitive performance and functional status (Chapters 2, 3, 4, 5). Secondly, an intervention that focused on executive functioning in older adults was evaluated, using cognitive complaints and cognitive functioning as dependent variables (Chapter 6). In addition, the effects of rehabilitation of hearing impairment by the use of hearing aids were examined with respect to auditory functioning, cognitive performance, well-being, and quality of life (Chapters 7, 8). This last Chapter is devoted to a discussion of general issues, which emerged from the empirical findings. Theoretical and practical implications are addressed and several methodological issues are discussed which are pertinent to cognitive aging research and to intervention studies in older adults.

Successful cognitive aging: the role of executive functioning

Adequate executive functioning is of major importance for successful cognitive aging. Indeed, in our study (Chapter 2) performance on a particular aspect of executive functioning showed more age-related differences than performance in other cognitive domains. A second reason concerns the role of executive functioning with respect to daily life activities and a person's actual functional status. Both aspects are discussed in detail below.

First, although it is well established that memory and information processing speed deteriorate in old age, the performance on tests that measure the inhibition of irrelevant stimuli, may show a significantly larger difference between age groups (Chapter 2; (Persad, Abeles, Zacks, & Denburg, 2002)). Inhibition is often considered an aspect of executive functioning (Miyake et al., 2000), and the diminished ability to inhibit irrelevant responses can result in the intrusion of irrelevant information in short-term memory. This hampers the efficient storage of information into long-term memory. As a consequence, performance on memory tests can be compromised (Zacks & Hasher, 1997). Other aspects of executive functioning (e.g. set-shifting and strategy-driven search in semantic memory) appeared to be less compromised than the other functions in healthy individuals aged 65 years and older (Chapter 2). These findings are in line with the notion that executive functioning should not be regarded as a unitary concept (Band, Ridderinkhof, & Segalowitz, 2002; Miyake et al., 2000), which implies that particular aspects of executive functioning deteriorate at an earlier age than others (Tisserand & Jolles, 2003).

Second, executive functioning has been associated with activities of daily living and with functional status, in particular with regard to physical functioning ((Cahn-Weiner, Boyle, & Malloy, 2002; Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000; Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998) Chapter 5). Although executive functioning was not a predictor of change in functional status, findings presented in Chapter 5 demonstrated that it was possible to make inferences from executive functioning to actual functional status. Executive functions are essential to plan activities, deal with novelty, solve problems, adapt to unexpected circumstances, and perform multiple tasks in the proper order and to monitor the stage of execution of multiple tasks. If executive functioning is inadequate, difficulties may arise in performing multiple activities of daily living, such as managing a home and finances. Thus, executive dysfunctioning may have a negative impact on the actual functional status of a person.

In summary, executive functioning appears to be crucial to successful cognitive aging, because certain executive functions show pronounced age-related differences and may have a major role in everyday activities. Therefore, it is important to investigate this aspect of cognitive functioning in more detail. Our findings may also have practical implications. Both professionals in clinical practice and older people themselves should receive more information about the pivotal role of this function in old age. It is therefore recommended to give more information to older adults about this aspect of cognitive functioning in order to increase the insight in cognitive functions older people have and how these relate to their personal capacities. Psycho-education, such as that given in Goal Management Training, is an example of an effective form of information transfer from professionals to people with complaints. Future research should investigate whether providing information about this cognitive domain increases knowledge and indirectly influences well-being and quality of life.

Determinants of successful cognitive aging

A main research question of this thesis concerned possible determinants of successful cognitive aging. Overall, it is clear that age per se has a profound influence on the decline of cognitive functions in older people (Chapter 3, Anstey, Stankov, & Lord, 1993). Nevertheless, age-extrinsic factors may also explain a proportion of this deterioration in addition to the age-related decline. Psychological factors, such as more depressive and anxiety symptomatology, hypertension, and low memory self-efficacy, have been found to be associated with diminished executive functioning and memory functioning in older adults (Chapter 3 and 4; Valentijn et al., in press; Den Hartog, Derix., van Bemmel, Kremer, & Jolles, 2003; Comijs, Jonker, Beekman, & Deeg, 2001). Cross-sectional studies have shown that a high level of physical functioning and a high level of social functioning may also be regarded as determinants of successful cognitive aging (Chapter 4). Comparison of the relative importance of psychological and physical factors showed, that psychological factors related to mood were more important than physical functioning for successful cognitive aging. At a population level, we showed that psychological functioning, i.e. feelings of anxiety or depression, were better predictors of cognitive changes over time than were physical problems (Chapter 4). Obviously, we only investigated a select set of factors and other relevant variables (e.g. of a neurobiological nature) may add further to age-related cognitive decline.

In summary, these findings suggest that age remains the best predictor of cognitive decline in older adults. Yet, the findings contain also a hopeful message, since several modifiable factors are identified that may distinguish a successful cognitive aging group from a normal cognitive aging group. Future research should evaluate these factors in more detail and provide clues as to the best way to use this information in interventions directed at supporting successful cognitive aging.

Interventions for older people

Neuropsychological interventions

Findings from the present thesis show that certain neuropsychological interventions can have beneficial effects on cognitive complaints and cognitive functions. As reported in Chapter 6, teaching people aged 55 years and older who experienced executive problems a strategy to improve planning activities in combination with psycho-education about the role of cognitive functions in daily life appeared to have a positive effect on subjective cognitive functioning. Despite modest effect sizes, this is an important finding, because this improvement may enable individuals to use better managing strategies and to cope with their cognitive problems more efficiently (Chapter 6). Further studies are needed to evaluate these findings and to investigate whether they can be generalized to patient groups and/or to related cognitive functions. In addition, results from the same research programme showed that a memory training programme targeting memory self-efficacy and memory strategies resulted in greater stability in memory functioning and fewer feelings of anxiety and stress about memory functioning in individuals aged 55 years and older. Moreover, positive effects were found on objective memory functioning (Valentijn et al., in press). These interventions were designed as group intervention programmes, an approach which provides people with the opportunity to learn from the problems of other participants and to evaluate the best coping mechanisms. In other words, these interventions also address 'attitudes' that can be considered important because it is increasingly recognized that training per se is not enough to achieve a significant behavioural change (Hambrick, Salthouse, & Meinz, 1999; Lachman, Weaver, Bandura, Elliott, & Lewkowicz, 1992). Furthermore, an important element of both interventions is psycho-education. The general objective of psycho-education is to increase a person's insight into the cognitive strengths and weaknesses and to help him/her to make use of relevant coping mechanisms more efficiently (Commissaris, Verhey, & Jolles, 1996). Neuropsychological interventions that focus on other cognitive domains, including reasoning and speed of information processing also have beneficial effects on cognitive functioning (Ball et al., 2002). Thus, several neuropsychological interventions are available that may have the potential to positively influence the targeted cognitive domain.

For implementation purposes, it is important to know whether these interventions are cost effective and reduce medical consumption. Further research should therefore address the economic evaluation of these interventions. In addition, applied research is needed to investigate whether specific personal characteristics nfluence the success of a specific intervention. For example, do individuals with a higher education benefit more from a neuropsychological intervention because othey have a greater insight into their complaints or problems? Or do lower educated people show more positive effects of interventions, because they are not familiar with the neuropsychological strategies? In addition, the interventions may be effective in other groups with similar problems or complaints. For example, the intervention directed at executive functions may also be effective in young adults who have problems with planning and organising activities in daily life.

Sensory interventions

Improvement or maintenance of cognitive functions may be achieved by neuropsychological interventions, but it is also possible to target the rehabilitation process on particular determinants of age-related cognitive decline and thereby indirectly promote successful cognitive aging. Cognitive aging research in the past decade has pointed to the role of sensory impairment in this respect. It was demonstrated in yet another study in this programme that rehabilitation of visual impairment by means of cataract surgery had a positive effect on memory and the ability to inhibit a habitual response (thesis by Valentijn[1]). However, rehabilitation of hearing impairment in older adults by means of hearing aid use did not have a positive effect on performance on cognitive tests with visual stimuli (Chapter 6). These inconsistent findings may be explained by the mode of presentation of the cognitive tests. Because all tests in both studies were presented visually, it is possible that a decreased efficiency of perception of visual information (Van Boxtel et al., 2000) or difficulty in paying attention to relevant stimuli (Baltes & Lindenberger, 1997; Rabbitt, 1990) gives rise to inferior consolidation of new information only in individuals with a visual impairment. These explanations are also in line with a study that demonstrated beneficial effects of hearing aid use on a cognitive test, which was presented auditorily (Mulrow et al., 1990). These explanations still may coexists with, or be complementary with the common cause hypothesis (Lindenberger & Baltes, 1997), which states that both cognitive functioning and sensory function may decline as a result of a 'common factor'. More specifically, this hypothesis predicts that improving sensory functioning will only have beneficial effects on the targeted sensory system, but will not affect a third common factor and as a consequence will not produce positive effects on cognitive functioning. From this perspective, the finding that hearing aid use did not improve cognitive functioning is in line with this hypothesis- while the hearing threshold was improved, cognitive performance did not. Thus, it seems unlikely that this intervention has implications for cognitive mechanisms in the central nervous system.

Overall, hearing aid use is regarded as a successful intervention for improving hearing threshold and reducing hearing handicap (Bess, 2000; Mulrow et al., 1990; Tesch-Romer, 1997) Chapter 7). Moreover, the findings of Chapter 7 indicated that this intervention positively influenced physical and social functioning, physical problems, mental health, and vitality in a subgroup of hearing aid users who experienced a subjective improvement of their hearing function. This finding may indicate that psychological factors related to using the equipment and the personal attitude about the use of a hearing aid may contribute more to the effect of the hearing aid than has hitherto been recognized. Thus, because hearing aid use may increase the quality of life, we recommended that older adults be screened for hearing impairments and offered adequate treatment to those who are impaired.

Successful Cognitive Aging: Quo Vadis?

The concept of successful aging (Baltes & Baltes, 1990; Rowe & Kahn, 1987, 1997) has gained substantial attention from many researchers in recent years. It is important to acknowledge that the aging process does not always lead to profound deterioration, and that a substantial

[1] Valentijn, S. (2004) *Succesful cognitive aging: memory, determinants, and interventions.* Doctoral Thesis, Maastricht University, Maastricht

proportion of the elderly population is able to reach advanced old age with a relatively good quality of life and relatively preserved functioning. This provides a refreshing and more positive alternative to the 'classic' perspective that focuses on the adverse consequences of aging. The role of cognitive functioning within the concept of successful aging has up till now not been quite clear. Researchers have used different definitions and operationalisations of successful aging (Berkman et al., 1993; Guralnik & Kaplan, 1989; Roos & Havens, 1991; Rowe & Kahn, 1987, 1997; Strawbridge, Cohen, Shema, & Kaplan, 1996). Some have included cognitive functioning in their definition and operationalisation (Berkman et al., 1993; Rowe & Kahn, 1987, 1997), while others have not even mentioned cognitive functioning (Guralnik & Kaplan, 1989; Roos & Havens, 1991). These various definitions and operationalisations can result in different statements and suggestions about successful aging. Therefore, it is important in successful aging research to consider the definitions and operationalisations of successful aging.

In this thesis, we focused on successful cognitive aging. The results showed that several factors explain why some individuals perform high on cognitive tests, particularly those probing the domain of executive functioning. The observation that specific interventions for older adults have the potential to change attitudes, reduce targeted cognitive complaints, and positively affect the quality of life paves the way to further study of the most effective ways to help older people use their remaining faculties as efficiently as possible and thereby promote quality of life.

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Summary

The number of older people is increasing rapidly. It is well established that the objective performance on cognitive tests declines with aging and the subjective appraisal of cognitive functioning by older persons changes. Interestingly, some older individuals show a decline in cognitive functioning, while others perform as good as young adults. This last cognitive aging trajectory is regarded as successful cognitive aging. The central theme of this thesis is to explore the determinants of successful cognitive aging and the effects of dedicated interventions for older people on aspects of cognitive function, quality of life, and general well being.

The rationale, aims, and research questions underlying the studies described in this thesis were presented in Chapter 1. Existing knowledge on successful cognitive aging was reviewed, with special emphasis on executive functioning. Empirical evidence on factors that may determine successful cognitive aging was concisely discussed. Background information was presented about the possibility to improve or maintain cognitive functioning, well-being, and quality of life in order to support successful aging.

Part I

The main objective of the studies described in part I was to investigate cognitive differences between age groups, the determinants and consequences of cognitive decline. The studies presented in this part all used data derived from the Maastricht Aging Study, a longitudinal study on determinants of normal cognitive aging.

The aim of the research presented in **Chapter 2** was to determine a possible differential effect of age on learning, working memory, and cognitive speed in healthy older adults and to evaluate the influence of education and sex. A group of 578 healthy participants aged 64 to 81 years was evaluated. Analysis of variance showed that there was a clear decrease in performance in terms of measures of learning, memory, and cognitive speed, with the most pronounced difference between the age groups being found for an executive functioning task. Education had a substantial effect on cognitive functioning: participants with a middle or high level of education performed better on cognitive tests than did participants with a low level of education. With respect to sex differences, women performed better than men on memory tasks, whereas there was no difference in the performance of simple and complex speed tasks. Since education and sex had a profound influence on particular cognitive functions in older people, these factors must be taken into account when examining an older individual's cognitive performance.

Previous studies have identified a number of factors, such as high blood pressure, diabetes, and heavy alcohol consumption, that are associated with executive functioning in old age. However, it is not clear whether these factors explain why older people have a worse performance than than younger individuals on tests of executive functioning. The study presented in the **Chapter 3** was designed to identify biological and psychological factors that could mediate the relationship between age and executive function. A group of 838 healthy individuals aged between 49 and 82 years was investigated. MAAS data from baseline and 3-year follow-up were included in the analyses. Linear regression models were used to compare the effect of age on the decline in performance on the Stroop Colour Word Test between models with and without correction for twelve biological and nine psychosocial factors. Of the factors investigated, prevalent hypertension and a low level of memory self-efficacy contributed to a poorer executive performance in the older individuals. The other factors contributed only marginally to the association between age and executive function. The findings of the present study suggests that age-extrinsic factors, such as those caused by illnesses or the environment, have only a minor role in explaining why older individuals perform worse than younger people on cognitive tests. However, the present findings underscore the notion that factors such as hypertension and memory self-efficacy should be evaluated further with regard to impaired cognitive functioning in older individuals.

The aim of the study described in **Chapter 4** was to determine whether health status (i.e. physical, social, and psychological functioning) is related to cognitive functioning and cognitive change over a 6-year period in older adults and to explore the relative contribution of the components of health status to long-term changes in cognitive function. The cognitive performance of a group of 669 participants aged 60 to 81 was assessed. Results indicated that older individuals with a high level of physical, social, and psychological functioning performed better on cognitive tasks, including those related to memory, executive functions, and speed of information processing. The most important component of health status in terms of its association with cognition was psychological functioning. In conclusion, poor psychological functioning, rather than poor physical and poor social functioning as measured by self-assessment appears to have the greatest effect on long term cognitive functioning in older people.

To date, it remains unclear to what extent cognitive competence is related to a change in general functional status in older adults. The study presented in **Chapter 5** evaluated the relation between cognitive functioning and functional status. Sensorimotor speed, memory, and executive functioning were assessed in a sample from the MAAS population, made up of healthy adults aged 60 years and older (n=485). Data from the baseline (1993-1995), 3-year follow-up, and 6-year follow-up were used. Functional status was measured using the 36-item Short-Form Health Survey, the scores of which were coded into a physical and a mental component summary score. After adjustment for age, sex, and educational level, a high level of cognitive functioning appeared to be associated with better functional status in the cross-sectional analysis. Longitudinal analyses demonstrated that cognitive functioning was not a predictor of functional status 3 or 6 years later. Thus while cognitive functioning is useful clinically for making judgements about the short-term functional status of an older person, it is not useful for predicting changes in a person's long-term (> 3 years) functional status.

Part II

As a consequence of the growing number of older people who wish to remain active member of society and keep a good quality of life, there is a need to investigate possible interventions aimed at improving the functioning of older adults. Although a whole range of interventions to improve cognitive functioning are nowadays available for older people, only a few have been empirically evaluated. The main research question of the second part was to examine whether interventions for older adults improve or maintain cognitive performance and positively affect quality of life and thereby promote successful aging.

Although executive functions are often compromised in older individuals, no study to date has evaluated neuropsychological interventions that focus on these cognitive functions in older adults. The aim of the study presented in **Chapter 6** was to examine the effect of a structured course on executive functioning in older adults. The course was based upon the principles of 'Goal Management Training' and involved training in combination with psycho-educational techniques. The aim of this intervention was to teach individuals a strategy to improve the efficacy and attitude towards planning activities and to structure intentions. The randomised controlled study involved 69 community dwelling older individuals aged 55 years and older who were assigned to the treatment group or a waiting list control group. There was a positive effect of the intervention in that participants in the intervention group were significantly less annoyed by their cognitive failures and better able to manage previously reported executive failures after the intervention than were controls. There were no effects on objective measures of cognitive functioning. The findings of this study indicated that a combination of psycho-education and training has the potential to change the attitude of older people towards their functioning.

Research has indicated that sensory impairments can interfere with quality of life and cognitive abilities. The effects of interventions to re-establish sensory functioning on quality of life and cognitive performance were examined in the studies described in Chapters 7 and 8. One study (**Chapter 7**) focused on the effects of hearing aid use on different aspects of cognitive function, such as memory, attention, executive functioning, and processing speed. The other study (**Chapter 8**) focused on the effects of hearing aid use on hearing-specific and general quality of life measures that have been adversely associated with hearing impairment. Participants who were fitted with hearing aids for the first time were compared with control participants with an equivalent hearing impairment, but who did not undergo the intervention. After a dual baseline measurement and fitting of the hearing aids, all participants were assessed again with neurocognitive tests after 12 months. At baseline and at follow-up assessments at 6 and 12 months, all participants filled in questionnaires on quality of life, depressive symptomatology, and subjective auditory ability. While the participants who were fitted with hearing aids had improved hearing thresholds, they did not have an improved performance on the cognitive tests. The analyses presented in Chapter 8 show that in the intention to treat analysis, hearing aid use did not have positive effects on general quality of life measures. Still, a subgroup of hearing aid users who experienced improved subjective auditory functioning reported better physical and social functioning, fewer physical problems, a better mental health, and more vitality after hearing aid use compared with the control group.

The practical and theoretical implications, which emerge from the empirical findings were discussed in **Chapter 9,** as were topics of future research and some general conclusions. On the basis of the results presented in this thesis, it can be conlcuded that executive functioning can be regarded to be a crucial aspect for successful cognitive aging, because particular executive functions show more pronounced age-related differences and may have a major role in everyday activities. Moreover, although age appears to be the best predictor of cognitive decline in older adults, age-extrinsic factors may also explain a proportion of the deterioration in addition to the age-related decline. Neuropsychological interventions for older adults appear to have the potential to positively influence (attitude towards) cognitive functioning.

Samenvatting

Het aantal ouderen neemt snel toe. Wanneer mensen ouder worden, nemen de objectieve prestaties op cognitieve tests af en de subjectieve ervaring ten aanzien van het cognitief functioneren verandert. Echter, er blijkt een grote variatie te bestaan met betrekking tot de cognitieve prestaties bij ouderen. Sommige ouderen laten een sterke afname van het cognitief functioneren zien, terwijl anderen even goed als jongeren presteren. Dit laatste traject wordt gezien als succesvol cognitieve veroudering. Het centrale thema van dit proefschrift is enerzijds het onderzoeken van de determinanten van succesvolle cognitieve veroudering en anderzijds het nagaan van de effecten van interventies voor ouderen op gebieden als cognitief functioneren, kwaliteit van leven en algemeen welbevinden.

De rationale, doelen en onderzoeksvragen die ten grondslag liggen aan de onderzoeken in dit proefschrift worden besproken in **hoofdstuk 1**. De bestaande kennis over succesvolle cognitieve veroudering wordt samengevat, waarbij de nadruk ligt op het executief functioneren. Daarnaast komen in dit hoofdstuk factoren aan de orde die succesvolle cognitieve veroudering kunnen bepalen. Vervolgens wordt er ingegaan op de mogelijkheid om het cognitief functioneren, welbevinden en kwaliteit van leven te verbeteren of te handhaven en zodoende succesvolle veroudering te stimuleren.

Deel I

De belangrijkste probleemstelling van de studies uit het eerste deel was het onderzoeken van cognitieve verschillen tussen leeftijdsgroepen en het bepalen van determinanten en gevolgen van cognitieve achteruitgang. Deze studies baseerden zich op data verkregen uit de Maastricht Aging Study, een longitudinale studie die zich richt op de determinanten van normale cognitieve veroudering.

Het doel van het onderzoek dat in **hoofdstuk 2** werd gepresenteerd, was het bepalen van mogelijke differentiële effecten van leeftijd op leren, werkgeheugen en cognitieve snelheid bij gezonde ouderen. Daarnaast werd de invloed van opleiding en geslacht geëvalueerd. Voor dit onderzoek werd een groep getest van 578 gezonde deelnemers tussen 64 en 81 jaar oud. Variantie analyses lieten een duidelijke afname zien wat betreft de cognitieve prestaties. De grootste verschillen tussen de leeftijdsgroepen waren te zien bij een executieve functie test. Opleiding had een substantieel effect op het cognitief functioneren, waarbij deelnemers met een gemiddelde of hoge opleiding beter presteerden op cognitieve tests dan deelnemers met een laag opleidingsniveau. Wat betreft geslachtsverschillen bleek dat vrouwen beter presteerden dan mannen op een geheugentaak, terwijl er geen verschillen waren in de prestatie op snelheidstaken. Omdat opleiding en geslacht een duidelijke invloed hebben op bepaalde cognitieve functies bij ouderen, is het van belang om met deze factoren rekening te houden wanneer cognitieve prestaties van ouderen worden geëvalueerd.

Eerdere studies hebben een aantal factoren geïdentificeerd die samenhangen met het executief functioneren bij ouderen. Voorbeelden van deze factoren zijn hoge bloeddruk, diabetes en het nuttigen van grote hoeveelheden alcohol. Het is echter niet duidelijk of deze factoren verklaren waarom ouderen slechter presteren dan jongeren op executieve functie tests. De studie die wordt beschreven in **hoofdstuk 3** was opgezet om biologische en psychosociale factoren te identificeren die de relatie tussen leeftijd en executief functioneren mediëren. Er werden 838 ouderen onderzocht in de leeftijd van 49 tot 82 jaar. MAAS data van de beginmeting en de meting na 3 jaar werden geïncludeerd in de analyses. Er werd gebruikt gemaakt van lineaire regressie modellen om de effecten van leeftijd op de afname in cognitieve prestatie te vergelijken met modellen met en zonder correctie voor twaalf biologische en negen psychosociale factoren. Het bleek dat zowel hypertensie als weinig vertrouwen in het geheugen een bijdrage levert aan slechtere executieve prestaties bij ouderen. De overige onderzochte factoren droegen slechts marginaal bij aan de associatie tussen leeftijd en het executief functioneren. De resultaten van deze studie suggereren dat leeftijd-extrinsieke factoren slechts een kleine rol spelen in het verklaren waarom ouderen slechter presteren dan jongeren op cognitieve tests. Maar deze bevindingen benadrukken dat factoren zoals hypertensie en het vertrouwen in het geheugen verder onderzocht zouden moeten worden in cognitief verouderingsonderzoek.

Het doel van de studie die in **hoofdstuk 4** wordt besproken, was het bepalen of de gezondheidsstatus (i.e. fysiek, sociaal en psychologisch functioneren) samenhangt met het cognitief functioneren en cognitieve verandering na 6 jaar. Verder werd onderzocht of de verschillende componenten van gezondheidsstatus evenveel samenhangen met cognitieve veranderingen. De cognitieve prestaties van 669 deelnemers tussen 60 en 81 jaar werden onderzocht. De resultaten lieten zien dat ouderen die goed fysiek, sociaal en psychologisch functioneren, beter presteerden op cognitieve taken. De belangrijkste component van gezondheidsstatus in relatie tot cognitie was psychologisch functioneren. Vanuit deze gegevens kan worden geconcludeerd dat slecht psychologisch functioneren, en niet zozeer slecht fysiek en sociaal functioneren, het sterkste effect blijkt te hebben op het cognitief functioneren van ouderen.

Tot nog toe blijft het onduidelijk in hoeverre cognitie gerelateerd is aan algemene functionele status bij ouderen. In de studie uit **hoofdstuk 5** werd de relatie onderzocht tussen cognitief functioneren en functionele status. Sensimotorische snelheid, geheugen en executief functioneren werden gemeten in een groep gezonde ouderen van de MAAS populatie, die 60 jaar en ouder waren (n=485). Er werd gebruik gemaakt van data van de beginmeting, de meting na 3 jaar en de meting na 6 jaar. Functionele status werd gemeten met de SF-36, waarbij de scores werden gecodeerd in een fysieke en mentale component. Nadat werd gecorrigeerd voor leeftijd, geslacht en opleidingsniveau bleek dat goede prestaties op cognitie functie tests samenhangen met een beter functionele status. Longitudinale analyses lieten zien dat het cognitief functioneren geen voorspeller was van functionele status 3 of 6 jaar later. Dus prestaties op cognitieve tests kunnen nuttig zijn om een oordeel te geven over de functionele status op de korte termijn, echter cognitieve prestaties blijken geen goede voorspeller te zijn voor lange termijn veranderingen in de functionele status.

Deel II

Als gevolg van het toenemend aantal ouderen dat actief wil blijven in de gemeenschap en een goede kwaliteit van leven wil behouden, is er behoefte aan het onderzoeken van interventies die zich richten op het verbeteren van het functioneren van ouderen. Ondanks dat er inmiddels al een hele reeks interventies beschikbaar is om het cognitief functioneren van ouderen te verbeteren, zijn er slechts zeer weinig empirisch geëvalueerd. De belangrijkste onderzoeksvraag van dit tweede deel van het proefschrift was om na te gaan of interventies voor ouderen het cognitief functioneren kunnen verbeteren of handhaven en de kwaliteit van leven positief beïnvloeden, waardoor succesvol ouder worden wordt gestimuleerd.

Ondanks dat executieve functies vaak afnemen bij ouderen, heeft tot nu toe geen enkele studie een neuropsychologische interventie voor ouderen geëvalueerd die zich richt op deze cognitieve functies. Het doel van de studie uit **hoofdstuk 6** was om het effect te onderzoeken van een gestructureerde cursus voor ouderen gericht op het executief functioneren. De cursus was gebaseerd op de principes van de Goal Management Training in combinatie met psycho-educatie technieken. Het doel van deze interventie was om mensen een strategie te leren om zodoende de efficiëntie en houding ten opzichte van planningsactiviteiten te verbeteren en om intenties te structureren. Deze gerandomiseerde gecontroleerde studie bevatte 69 deelnemers die 55 jaar en ouder waren. De deelnemers werden toegewezen aan een interventiegroep of een wachtlijst controle groep. De deelnemers vanuit de interventiegroep waren na de cursus significant minder geïrriteerd door hun cognitieve missers en konden beter omgaan met de eerder genoemde executieve vergissingen. Er was geen effect wat betreft de cognitieve testprestaties. De bevindingen van deze studie laten zien dat een combinatie van psycho-educatie en training de potentie heeft om de attitude van ouderen ten opzichte van hun functioneren te veranderen.

Eerder onderzoek heeft aangetoond dat sensorische problemen kunnen interfereren met kwaliteit van leven en cognitieve vermogens. De effecten van interventies om het sensorisch functioneren te verbeteren op kwaliteit van leven en cognitieve prestaties werden onderzocht in de studies die worden beschreven in hoofdstuk 7 en 8. De eerste studie richtte zich op de effecten van het gebruik van een hoortoestel op verschillende aspecten van het cognitieve functioneren (**hoofdstuk 7**). De andere studie richtte zich op de effecten van het gebruik van een hoortoestel op gehoorspecifieke en algemene kwaliteit van leven variabelen die negatief samenhangen met hoorproblemen (**hoofdstuk 8**). Deelnemers die voor de eerste keer hoortoestellen kregen aangemeten werden vergeleken met controle deelnemers met een vergelijkbare gehoorsafname, maar die geen interventie ondergingen. Na een dubbele beginmeting en aanpassingen van de hoortoestellen, werden alle deelnemers wederom getest na 6 en 12 maanden. Alle deelnemers vulden ook vragenlijsten in over kwaliteit van leven, depressieve symptomen en subjectieve gehoorsfunctie. Deelnemers vanuit de interventiegroep hadden betere hoordrempels na het gebruik van het hoortoestel, maar zij presteerden niet beter op cognitieve tests na het gebruik van het hoortoestel in vergelijking met de controle groep. De analyses vanuit hoofdstuk 8 tonen aan dat het gebruik van een hoortoestel geen positieve effecten had op algemene kwaliteit van leven. Toch rapporteerde een subgroep van de hoortoestelgebruikers beter fysiek en sociaal functioneren, minder fysieke problemen, een betere mentale gezondheid en meer vitaliteit na het gebruik van een hoortoestel in vergelijking met de controle groep.

De praktische en theoretische implicaties die voortvloeien uit de empirische bevindingen worden bediscussieerd in **hoofdstuk 9**. Tevens worden enkele algemene conclusies en toekomstig onderzoek besproken. Op basis van de resultaten vanuit dit proefschrift kan worden geconcludeerd dat het executief functioneren kan worden gezien als een cruciaal aspect voor succesvol cognitief ouder worden, omdat bepaalde executieve functies duidelijkere verschillen tussen leeftijdgroepen laten zien en een belangrijke rol kunnen spelen in alledaagse activiteiten. Bovendien kan worden geconcludeerd dat leeftijdsextrinsieke factoren een deel van de proportie van cognitieve achteruitgang verklaren, ondanks dat leeftijd de beste voorspeller lijkt te zijn van cognitieve achteruitgang. Neuropsychologische interventies voor ouderen lijken de potentie te hebben om een positieve invloed uit te oefenen op de attitude ten opzichte van het cognitief functioneren.

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Curriculum Vitae

Susan van Hooren werd geboren op 9 november 1976 te Heerlen. Na het behalen van het Gymnasium diploma in 1995 aan het Sintermeertencollege te Heerlen, ging ze Psychologie studeren aan de Universiteit Maastricht. Gefassineerd door de relatie tussen het gedrag en het brein, koos ze de afstudeervariant biologische psychologie met als afstudeerrichting Neuropsychologie. Gedurende haar studie heeft ze meerdere malen als tutor opgetreden bij de Faculteit Psychologie van de Universiteit Maastricht. De stageperiode voltooide ze bij de Korsakov Kliniek van het Vincent van Gogh instituut te Venray, alwaar zowel onderzoek als klinische diagnostiek tot haar takenpakket behoorde. In 1999 behaalde ze het doctoraal diploma en aansluitend werd ze aangesteld als klinische neuropsycholoog bij de geheugenpolikliniek van het academisch ziekenhuis Maastricht. In 2000 startte ze als assistent in opleiding bij de vakgroep Psychiatrie en Neuropsychologie van de Universiteit Maastricht, waar zij tot 2004 werkte aan dit proefschrift. Na deze periode werd ze aangesteld bij de academische afdeling Neuropsychologie van het Psychomedisch Streekcentrum Vijverdal te Maastricht, alwaar haar taken bestonden uit het rapporteren van onderzoeksresultaten en het verrichten van klinische diagnostiek. Momenteel is ze werkzaam als Universitair Docent Neuropsychologie bij de Open Universiteit Nederland.

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Van Hooren S. A. H., Valentijn S. A. M., Bosma H., Ponds R. W. H. M., van Boxtel M. P. J., & Jolles J. (in press). Relation between health status and cognitive functioning: 6-year follow-up of the Maastricht Aging Study. *Journal of Gerontology: Psychological Sciences*.

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