Cognitive Functioning in Healthy Older Adults Aged 64–81: 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 cognitive speed, verbal memory, executive functioning, and verbal fluency 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 executive functioning, verbal fluency, verbal 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 verbal memory tasks. Therefore, education and sex must be taken into account when examining an older individual’s cognitive performance.

As the proportion of older people is increasing rapidly in the developed world, it is imperative to evaluate cognitive functioning in older adults and the possible influence of factors that determine age-related cognitive differences. This is because the factors 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 aging (Rowe & Kahn, 1987).

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Many studies have demonstrated that certain cognitive functions diminish with increasing age. Information processing speed is compromised (Houx & Jolles, 1993; Jolles et al., 1993), as is efficient consolidation of newly learned information (Salthouse, 1998). In addition, problems appear in executive functions such as planning and behavioral organization (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).

Above age, a number of individual differences may impact these domains of cognitive functioning. 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 et al., 2001; Houx & Jolles, 1993; Van Boxtel et al., 1998). Other factors that are regarded as potentially important are education and sex. 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 et al., 2003; Elias et al., 1997; Evans et al., 1993; Lyketsos et al., 1999). People with a high level of education may have a greater “cognitive reserve capacity” than people with lower levels of education. When people with a larger cognitive brain reserve capacity are confronted with factors that have a negative impact on cognitive functioning, cognitive problems may emerge in a later phase (Stern, 2003). Sex may also impact cognitive functioning. Overall, it has been shown that women outperform men on verbal abilities and men perform better on visuospatial tasks. Yet many studies did not find a significant difference between the sexes on verbal tests, spatial tests, and other cognitive tests (Lezak et al., 2004). Few studies have focused on differences between sexes in a group of older adults. Herlitz et al. (1997) investigated memory functioning in 530 women and 470 men (aged 35–80 years) and identified sex differences in episodic memory, in favor of women. 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). It has been suggested that these sex differences may be due to task demands that differentially engage male or female interest, familiarity, or motivation (McKelvie et al., 1993), while other researchers suggested that these differences may be explained by biological differences between men and women, such as brain asymmetry (Lezak et al., 2004). These findings of the above-mentioned studies on education and sex 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).
Unfortunately, studies that have used a broad age range of participants are limited by cohort effects (Lezak et al., 2004; Schaele, 1994; Schretlen et al., 2000). In the present study, we included a small age range (64–81 years) in order to minimize 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.

Thus more needs to be learned about the possible differential effects of age on the major cognitive domains of cognitive speed, executive functions, verbal memory, and verbal fluency 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 et al., 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 aging. The present study was devised with the aim to provide this information.

We investigated whether differences between age groups are similar for various cognitive functions, such as cognitive speed, executive functioning, verbal memory, and verbal fluency functions which are especially sensitive to aging 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 hypothesized 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 aging (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 MAAS, a large-scale population study examining determinants of cognitive ageing. The aim,
population characteristics, and design of MAAS are reported elsewhere (Jolles et al., 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 (RNH) (Metsemakers et al., 1992)). Medical exclusion criteria, based on data from the RNH, were active coma, cerebrovascular pathology, all tumors of the nervous system, congenital malformations of the nervous system, multiple sclerosis, parkinsonism, epilepsy, dementia, organic psychosis, schizophrenia, affective psychosis, and mental retardation. In addition, all participants were screened in a semi-structured interview to update the RNH data and to check for exclusion criteria not included in the RNH database. The additional exclusion criteria included history of transient ischemic attacks (TIA), brain surgery, hemodialysis for renal failure, electro convulsive therapy, and regular use of psychotropic drugs. In addition to medical exclusion criteria, participants were enrolled if they had a score of 24 or more on the Mini-Mental State Examination (MMSE) (Folstein et al., 1975). The sample of men and women 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 Color Word Test (SCWT) involves three cards displaying 100 stimuli each (Houx et al., 1993; Stroop, 1935). The first card contains
color words printed in black ink, which have to be read. The second card contains colored patches, which have to be named. The last card displays color names printed in incongruously colored ink. Participants are instructed to name the ink color 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.

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 trials, the total score of the first three trials is used as a 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 & Lusczcz, 2000; Persad et al., 2002).

Statistical Analyses

Differences in demographic variables (i.e., sex and educational level) between age groups were analyzed with chi-square tests. A multiple analyses 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 (.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 as expected that because of the applied stratification procedure, the age groups were comparable with respect to sex and education.

Table 2 summarizes standardized adjusted means of cognitive outcome measures by age group. Analysis of variance showed that the age groups differed significantly on all cognitive measures ($p < .01$). In order to better illustrate the strong age-related cognitive differences, the differences in standardized cognitive performance were calculated for each age group, using the youngest age group as a reference group (Figure 1). Additional analyses were performed to adjust for IQ score. Overall, a similar pattern of results was found: age groups differed significantly on all cognitive measures. Multivariate analysis including all cognitive measures (standardized) 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 [$F(7, 524) = 1.35, p = .23$], because of standardization. The interaction between type of test and age group was significant [$F(21, 1568) = 1.71, p = .03, \eta^2 = .016$]. Specified contrasts showed that the differences between the age groups in verbal

| Table 1: Demographic Characteristics of the Participants in the Study By Age Group |
|----------------------------------|---|---|---|---|---|
| N                               | 65 | 70 | 75 | 80 | p-Value |
| Sex (% male)                    | 20.0% | 51.8% | 30.3% | 49.5% | .982 |
| Education (1-3)                 | 59.4% | 58.4% | 60.5% | 67.6% | .139 |
| % low                           | 25.0% | 25.9% | 23.3% | 9.5% |
| % middle                        | 15.2% | 15.7% | 16.3% | 23.0% |
Table 2. Adjusted Means of Cognitive Performance by Age Group

<table>
<thead>
<tr>
<th></th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
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<td><strong>N</strong></td>
<td>164</td>
<td>164</td>
<td>169</td>
<td>72</td>
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<td><strong>SCWT</strong></td>
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<tr>
<td>SCWT-12*</td>
<td>53.8 (9.0)</td>
<td>54.0 (8.5)</td>
<td>57.7 (9.3)</td>
<td>59.6 (9.1)</td>
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<tr>
<td>SCWT-1*</td>
<td>53.6 (20.2)</td>
<td>60.7 (36.9)</td>
<td>66.7 (25.3)</td>
<td>87.5 (34.59)</td>
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<td><strong>CST</strong></td>
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<td>CST-ab*</td>
<td>27.4 (6.5)</td>
<td>28.8 (6.4)</td>
<td>31.4 (8.1)</td>
<td>34.3 (8.9)</td>
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<tr>
<td>CST-1*</td>
<td>14.7 (9.8)</td>
<td>18.2 (17.9)</td>
<td>19.1 (13.5)</td>
<td>21.4 (19.4)</td>
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<td><strong>LDST</strong></td>
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<td>40.0 (9.2)</td>
<td>39.4 (9.0)</td>
<td>36.2 (9.5)</td>
<td>32.3 (7.9)</td>
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<td><strong>VVLT</strong></td>
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<td>Immediate recall</td>
<td>21.1 (5.5)</td>
<td>19.7 (5.1)</td>
<td>18.2 (4.8)</td>
<td>16.1 (4.9)</td>
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<tr>
<td>Delayed recall</td>
<td>8.9 (2.7)</td>
<td>7.8 (3.1)</td>
<td>7.2 (3.0)</td>
<td>5.7 (2.8)</td>
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<td><strong>Fluency</strong></td>
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<td></td>
<td>22.7 (6.4)</td>
<td>21.7 (5.6)</td>
<td>20.3 (5.3)</td>
<td>19.7 (5.4)</td>
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</table>

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

SCRT variables, CST variables, and LDST were expressed in seconds to complete.

VVLT and Fluency represented the number of words recalled.

* Higher scores reflect poorer performance.

**p < .01.

***p < .001.

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

Fluency [F(3, 534) = 3.08, p = .03; eta² = .017] and CST-1 [F(3, 534) = 2.78, p = .04; eta² = .02] were significantly less pronounced than for the other cognitive measures. In contrast, the differences between the age groups in SCRT-1 performance were significantly more pronounced than for the other measures [F(3, 534) = 2.96, p = .03; eta² = .017].

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 < .01). The effect sizes range from 0.013 (VVLT delayed recall) to 0.132 (LDST). Scheffé post-hoc tests...
| 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* | 57.7 (9.2) | 53.6 (8.4) | 52.0 (8.7) | *** | 56.2 (9.3) | 55.3 (9.1) |
| SCWT-i* | 69.2 (14.5) | 54.9 (20.1) | 55.9 (20.7) | *** | 64.2 (33.4) | 63.3 (27.2) |
| CST | | | | | |
| CST-ab* | 31.7 (8.0) | 27.6 (9.1) | 26.6 (5.4) | *** | 30.0 (7.6) | 29.8 (7.6) |
| CST-i* | 20.0 (15.0) | 17.1 (17.1) | 11.3 (8.8) | *** | 17.1 (14.0) | 18.7 (16.1) |
| LDST | | | | | |
| | 35.0 (8.8) | 41.9 (8.9) | 43.5 (8.2) | *** | 38.3 (9.5) | 37.6 (9.5) |
| VVLT recall | | | | | |
| Immediate recall | 18.6 (5.0) | 20.0 (6.1) | 20.2 (5.4) | *** | 18.1 (5.1) | 20.3 (5.4) | *** |
| Delayed recall | 7.4 (2.9) | 8.2 (3.3) | 7.9 (3.2) | *** | 6.9 (3.0) | 8.4 (3.0) | *** |
| Fluency | 20.2 (5.4) | 22.2 (5.7) | 24.1 (6.2) | *** | 21.5 (5.9) | 21.1 (5.8) |

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

SCWT variables, CST variables, and LDST were expressed in seconds to complete.

VVLT and Fluency represented the number of words recalled.

* Higher scores reflect poorer performance

***p < .01

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 < .01] and delayed recall [F(3, 551) = 47.98, p < .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. The effect sizes ranged from smaller than 0.001 (SCWT-I and LDST) to 0.048 (VVLT delayed recall). Adjusting for IQ score did not have a major impact on the results: a higher educational level was associated with higher scores on cognitive tests (except for verbal memory and verbal fluency), and women performed better than men on verbal memory tasks.

**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 cognitive speed, executive functioning verbal memory, and verbal fluency. This is consistent with previous studies that reported either significant correlations with age or significant differences across age groups with respect to comparable cognitive tests included in this study, such as the Stroop Color Word Test, Verbal Fluency, Trail Making Test, and the Symbol Digit Modalities Test (Lezak et al., 2004; Mitrushina et al., 1999; Spreen & Strauss, 1998). These results support 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 (Hanininen 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 and 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 et al., 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.

Another explanation for the present result may concern the hypothesis of effortful or controlled processing (e.g., Broadbent, 1977; Hasher & Zacks, 1979; Logan, 1989). Some tasks require more active and effortful processing, which is slower and dependent on intention, strategy, and attentional resources. In contrast, in automatic processing stimuli are encoded in a fast, passive, effortless manner. The interference score of the Stroop Color Word Test has been regarded as a task that requires effortful processing and therefore the performance may show more differences between age groups. However, performance on other complex and effortful tasks, such as the interference score of the Concept Shifting Task, did not show more pronounced differences between age groups.

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 the level of education in a community population of people older than 65 (Evans et al., 1993; Lezak et al., 2004; Lyketsos et al., 1999; Mitrushina et al., 1999; Spreen & Straus, 1998). Several explanations for the relation between educational level and cognitive functions can be suggested. First, people with a lower level of education may have less brain reserve capacity, and therefore cognitive symptoms are more likely to emerge after an insult to the brain (Stern, 2003). Second, higher educated people may lead different lifestyles in their eating habits, exercise habits, pesticide exposure, etc. This
may have an impact on specific aspects of health status, such as cardiovascular status, which may be related to cognitive functioning. Another 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 MMSE, was associated with a lower level of education. Likewise, noneducated 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 verbal 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 et al., 2000; Rabbit et al., 1995; Unverzagt et al., 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 et al., 1997). Biological mechanisms, such as atherosclerosis, could also account for these differences (Van Exel et al., 2001), since men are more likely to have atherosclerosis. This may cause subclinical, ischemic events in the brain, which may contribute to cognitive decline in older people (Breteler et al., 1994; Kilander et al., 1997). 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 menopause. Studies have suggested that estrogen replacement therapy can promote cognitive functions in older women (Hogervorst et al., 1999).

The study population consisted of a large number of older adults, with no major cognitive problems and diseases that may seriously affect cognitive functioning. Therefore, the results of the present study can be applied to healthy older people.

In conclusion, differences in cognitive speed, executive functioning, verbal memory, and verbal fluency 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.

ACKNOWLEDGMENTS

This study was conducted in close collaboration with the Registration Network Family Practices and related general practitioners. The study was funded in part by a grant from the Dutch Ministries of Education and Health and Welfare via the Steering Committee for Gerontological Research (NESTOR) and from the Dutch Research Council (NWO: 014-91-047). We would like to thank Richel Lousberg for his help with the statistical analysis.

Original manuscript received July 14, 2004
Revised manuscript accepted November 18, 2004
First published online October 13, 2006

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Aging and Capacity in the Same-Different Judgment

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ABSTRACT

The same-different judgment was used in two experiments to investigate age-group differences in visual processing. Two targets next to fixation were presented; the targets on one-half of the trials were the same, and on the other half of the trials, the targets differed by color, shape, or color and shape (redundant). Response times were lower for redundant trials than for color-only and shape-only trials; this redundancy gain was greater for older observers than for young observers. Capacity measures based on the integrated hazard functions indicated that young adults, but not older adults, experienced a slowing of processing (reduction of capacity) in the redundant condition. These capacity measures provide a method for interpreting age-group effects in the presence of overall response-time differences.

At present, there is no grand unifying theory to explain age-related differences in cognition (Salthouse & Craik, 2000; Salthouse, 2004). Two global descriptions of age-group effects, each of which has a lot of explanatory power, are reductions in speed (generalized slowing) (Cerella, 1990; Salthouse, 1992) and reductions in capacity (Salthouse, 1988). Measuring speed or capacity is a nontrivial problem, although each possesses an ordinal relationship to output measures such as response time (RT) or accuracy. Recent research has used explicit models such as the diffusion model to map speed onto response time, in order to characterize age-group differences in the rate of information acquisition (e.g., Thapar et al., 2003). Capacity, however, is less well-defined; as Wenger and Gibson (2004) pointed out, that concept is susceptible to problems of circularity and reification (cf. Navon, 1984; Salthouse & Craik, 2000).