Education does not protect against age-related decline of switching focal attention in working memory

Pascal W.M. Van Gerven a,*, Willemien A. Meijer b, Jelle Jolles a,b

a Maastricht University, Faculty of Psychology, Department of Neurocognition, Maastricht, The Netherlands
b Maastricht University, Faculty of Medicine, Department of Psychiatry and Neuropsychology, Maastricht, The Netherlands

Accepted 7 February 2007
Available online 29 March 2007

Abstract

In this experimental study, effects of age and education on switching focal attention in working memory were investigated among 44 young (20–30 years) and 40 middle-aged individuals (50–60 years). To this end, a numeric n-back task comprising two lag conditions (1- and 2-back) was administered within groups. The results revealed a comparable increase of reaction time as a function of lag across age groups, but a disproportionate decrease of accuracy in the middle-aged relative to the young group. The latter effect did not interact with education, which challenges the cognitive reserve hypothesis. Moreover, the high-educated middle-aged participants showed a greater increase of reaction time as a function of lag than their low-educated counterparts. Apparently, they were not able to sustain their relatively high response speed across conditions. These results suggest that education does not protect against age-related decline of switching focal attention in working memory.

Keywords: Aging; Cognitive reserve; Education; Working memory; Focal attention

1. Introduction

Focal attention in working memory is a relatively new concept in cognitive aging research. It was only recently added to the range of elementary cognitive control mechanisms that are compromised in older individuals (Verhaeghen & Basak, 2005; Verhaeghen et al., 2007; Verhaeghen, Cerella, Bopp, & Basak, 2005; Verhaeghen & Hoyer, 2007). The “focus of attention” (Cowan, 1988) can be defined as that part of working memory that is currently being processed. Other parts of working memory remain in the so-called “region of immediate access.” The capacity of focal attention is limited. Some researchers even assert that it does not exceed a single item (e.g., Garavan, 1998; McElree, 2001; but see Verhaeghen, Cerella, & Basak, 2004). Therefore, tasks with changing target items require switches of focal attention. Switching focal attention involves costs in terms of increased response time and reduced accuracy (McElree, 2001). Verhaeghen and Basak (2005) found accuracy costs to be larger in older (mean age = 72.15 years) than in younger individuals (mean age = 18.79 years).

The main question of the present study is whether the reduced ability of older individuals to switch focal attention is determined by the level of educational achievement. Education is a well-established proxy of “cognitive reserve,” a hypothetical construct referring to the ability of an individual to cope with age-related brain decline by employing compensatory strategies and recruiting alternative neural networks (e.g., Staff, Murray, Deary, & Whalley, 2004; Stern, 2002). Recently, cognitive reserve was

* We thank Renate de Groot and Ron Keulen for their excellent organizational support during this project. Anita van Oers is gratefully acknowledged for programming the E-Prime tasks. We also thank Lia Baars and Angelique Gijsen for testing the participants. Finally, we thank two anonymous reviewers for their constructive comments on an earlier version of this article.

** Corresponding author. Fax: +31 43 3884125.
E-mail address: p.vangerven@psychology.unimaas.nl (P.W.M. Van Gerven).
associated with increased activation of specific brain areas under high memory load (Stern et al., 2005). Furthermore, recent behavioral research suggests that age-related cognitive decline is considerably attenuated by educational achievement (e.g., Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006a). Others, however, have questioned the idea that higher educated and more intelligent individuals show decelerated cognitive aging relative to individuals with a lower mental ability (e.g., Rabbitt, Chetwynd, & McInnes, 2003). Indeed, a recent study by Christensen et al. (2007) has shown that the protective influence of education on cognitive aging is limited. This might be a general limitation, but the influence of education might also depend on the specific cognitive domain that is investigated. We believe that focal attention in working memory is particularly sensitive to individual differences in education.

An established paradigm to study focal attention in working memory is the n-back paradigm (McElree, 2001), which involves the comparison of a current stimulus with a stimulus that was presented n stimuli before in a sequential presentation. Kwong See and Ryan (1995) found that the effect of age on n-back performance is considerably mediated by inhibitory efficiency. This suggests that the n-back task involves frontal lobe activity (cf. Braver & Barch, 2002; Dempster, 1992), which was indeed found in imaging studies (e.g., Jaeggi et al., 2003). It is well established that functions ascribed to the prefrontal cortex, notably inhibition, response planning, and other aspects of executive functioning, are particularly vulnerable to cognitive aging (e.g., Tisserand & Jolles, 2003). Less well established is the idea that age-related decline of these functions may be compensated by cognitive reserve. Yet, we do know that n-back performance depends on intellectual ability, notably information processing speed and working memory capacity (Hockey & Geffen, 2004). Furthermore, there is ample reason to suspect that educational achievement— as an estimate of cognitive reserve—generally determines executive functioning in older adults (e.g., Haut et al., 2005; Le Carret et al., 2003; Scarmeas et al., 2003).

In the current experimental study, we tested this hypothesis for the ability to switch the focus of attention within working memory by applying the n-back task. This task was originally devised by Dobbs and Rule (1989) to study age differences in working memory. The procedure is to present participants with a random series of items (usually digit between 1 and 9), which are presented one at a time. For every item, the participant has to decide as quickly as possible whether it is the same as the item that was presented n items before. The idea is that attention in working memory is focused on the n-back item. With every new item appearing, the focus of attention must be switched to a new n-back item. If n = 1, memory load is limited to one item, which is also the focus of attention. When a new item is presented, the old item in the focus of attention is simply replaced by the previously presented item. If n > 1, working memory must maintain multiple items and the focus of attention is switched from one item to the other. Verhaeghen and Basak (2005) found reaction time to equally increase with lag (n) across age groups. Accuracy, however, disproportionately decreased as a function of lag in the older compared to the younger participants. When n was increased beyond 2, however, the difference in accuracy between the age groups did not grow any further. This was taken as evidence that (1) increasing n from 1 to 2 is critical in that it introduces the need to switch focal attention, and (2) older individuals have more difficulty with switching focal attention than their younger counterparts.

The sample used in the current study included young (20–30 years) and middle-aged (50 to 60 years) individuals, who were assigned to either a low- or high-educated group. Middle age is relatively underexposed in cross-sectional aging research. This is unfortunate both from a fundamental and from a strategic perspective as this is a particularly interesting group. It potentially reveals important information about the first signs of age-related cognitive decline as well as the determinants of decline at a later age. Moreover, research suggests that middle-aged people are likely to already show signs of age-related cognitive decline, especially in tasks that require cognitive control, such as the Stroop task (e.g., Houx, Jolles, & Vreeeling, 1993) and the Letter-Digit Substitution Test (LDST; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006b). At the same time, middle-aged people have not yet reached the age of retirement, which makes them relatively well comparable to younger adults. To exclude any age-extrinsic pathology that could interfere with cognitive performance, we extensively screened our participants for physical and psychological health problems.

2. Method

2.1. Participants

The sample consisted of 84 volunteers and was stratified according to age (young, middle-aged), sex, and educational level (low, high). A full description of the sample, including years of education, is given in Table 1. Participants were recruited in Maastricht and surroundings via advertisements in local newspapers, flyers, and contacts with local clubs (e.g., related to sports and music). A selection procedure was conducted by telephone to exclude persons with health-related conditions that are known to interfere with normal cognitive functioning. Exclusion criteria were cerebrovascular pathology, psychiatric disturbances, neurological disorders, dyslexia, renal dialysis, excessive use of alcohol (more than 21 consumption per week), use of psychoactive medication or drugs, and clinically overt visual or auditory deficits. Level of education was determined according to a standardized Dutch classification system (De Bie, 1987), which is comparable to the International Standard Classification of Education (UNESCO, 1976). This classification system comprises eight ordinal categories: (1) primary education, (2) lower voca-
tional education, (3) intermediate secondary education, (4) intermediate vocational education, (5) higher secondary education, (6) higher vocational education, (7) higher professional education, and (8) university education.

The younger group (mean age = 25.01 years; SD = 3.21) consisted of 18 low- (8 men, 10 women) and 26 high-educated people (13 men, 13 women) aged between 20 and 30 years. The middle-aged group (mean age = 56.14 years; SD = 3.43) consisted of 20 low- (10 men, 10 women) and 20 high-educated people (10 men, 10 women) between 50 and 60 years. In the Netherlands, just like in many other Western countries, people in the middle-aged cohort, who received their education before the 1960s, often did not finish or continue their schooling for reasons other than their intellectual capacity (Jolles, Houx, Van Boxtel, & Ponds, 1995). Therefore, persons between 50 and 60 years are generally lower educated than persons between 20 and 30 years (Mares, 2004). As a consequence, the median educational level in the population differs for the cohorts that were sampled in the present study. We attempted to deal with this cohort effect by adjusting the classification into a low and a high educational level according to the median level in the population. In the young group, low education was defined as a maximum of intermediate vocational education (category 4; equivalent to a maximum of 13 years of education). In the older group, low education was defined as a maximum of intermediate secondary education (category 3; equivalent to a maximum of 10 years of education). By doing so, the mean difference in educational level between the low and the high-educated group was 2.93 for the young and 2.95 for the middle-aged participants, which is highly comparable. The mean difference in years of education between the low and the high-educated group was 3.94 for the young and 3.80 for the middle-aged participants, which is also highly similar. It should be noted that the mean years of education in Table 1 reflects the number of years that were reported by the participants themselves. These numbers can deviate from the number of years that are formally needed to complete a certain educational level (e.g., because people did not finish their schooling or took more time to finish it).

2.2. N-back task

The n-back task was programmed in E-Prime 1.1 (Psychology Software Tools, Pittsburgh, PA) and presented on a computer screen. In each of the two n conditions, a sequence of n + 32 digits was presented one at a time (cf. McElree, 2001). A response was required for every newly presented digit, starting after the nth digit of the sequence. Thus, 32 responses (trials) were recorded in each condition. In the 1-back condition, the participant was required to judge whether the current digit was the same as the previous digit in the sequence. In the 2-back condition, the participant was required to judge whether the current digit was the same as the one that was presented two digits back.

2.3. Design and procedure

Age group (younger, middle-aged) and education (low, high) were the between-groups independent variables. Lag (1-back, 2-back) was the within-groups independent variable. The order of the lag conditions was counterbalanced: half of the participants first received the 1-back condition and then the 2-back condition; the other half received these conditions in the reversed order.

Dependent variables were reaction time (ms) and accuracy (percentage correct). Responses were registered through a response box with two buttons labeled “yes” and “no.” Response button assignment was counterbalanced. That is, half of the participants had to press the left button as a “no” response and the right button as a “yes” response, whereas the other half received opposite instructions.

The procedure was similar to the one used by Van Gerven, Meijer, Prickaerts, and Van der Veen (in press). There were 32 trials in every condition, which were preceded by eight practice trials. In half of the trials the current stimulus matched the n-back stimulus; in the other half of the trials the current stimulus did not match the n-back stimulus. Participants were instructed to respond as quickly and accurately as possible. They did not receive feedback about their responses. Stimulus digits were presented for 500 ms on a 17-in. display. The size of the digits on the display was approximately 0.9 × 1.3 cm. The time interval between subsequent digits was 2500 ms.

3. Results

All data were analyzed with a 2 (age group) × 2 (education) × 2 (lag) repeated-measures analysis of variance (ANOVA). The alpha level was set to .05. Effect sizes are

---

Table 1
Descriptive statistics of the sample

<table>
<thead>
<tr>
<th>Age</th>
<th>Education</th>
<th>Years of education</th>
<th>Young (n = 44)</th>
<th>Middle-aged (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
</tr>
<tr>
<td>Age</td>
<td>24.92</td>
<td>25.07</td>
<td>3.47</td>
<td>3.08</td>
</tr>
<tr>
<td>Education</td>
<td>3.72</td>
<td>6.65</td>
<td>0.57</td>
<td>0.56</td>
</tr>
<tr>
<td>Years of education</td>
<td>13.44</td>
<td>17.38</td>
<td>1.79</td>
<td>2.55</td>
</tr>
</tbody>
</table>

Note: Education ranges from 1 (primary education) to 8 (university education).
reported as partial eta-squared ($\eta^2_p$). Post-hoc power analyses were performed using the GPOWER software package (Faul & Erdfelder, 1992).

3.1. Reaction time

Only reaction times corresponding to correct trials were analyzed. A natural log transformation was performed to correct for non-normality. Both the untransformed and log-transformed reaction times were analyzed. Results of the log-transformed data are only reported if they differ from the analyses of the untransformed data. Mean reaction times and standard errors are shown in Fig. 1. For clarity, mean “switch cost” of focal attention—that is, reaction time in the 2-back condition minus reaction time in the 1-back condition—is also depicted in Fig. 1. No analyses were performed on these data, however. The post-hoc power of the analyses was .71 for the between-groups main effects and .99 for the within-groups main effects and interactions.

The ANOVA revealed a main effect of age group, $F(1, 80) = 22.10$, $MSE = 38,645.62$, $p < .001$, $\eta^2_p = .22$, indicating that the middle-aged participants were significantly slower than the younger participants. There was also a marginally significant main effect of education, $F(1, 80) = 3.51$, $p = .065$, $\eta^2_p = .042$, which indicates that the low-educated participants responded slightly slower than the high-educated participants. This effect was significant for the log-transformed reaction times, $F(1, 80) = 4.36$, $MSE = 0.07$, $p < .05$, $\eta^2_p = .052$. Finally, there was a main effect of lag, $F(1, 80) = 258.28$, $MSE = 12,699.89$, $p < .001$, $\eta^2_p = .76$, which suggests that responses slowed down if people were compelled to switch focal attention.

The effect of lag did not interact with age group ($F < 1$), but did so for the log-transformed reaction times, $F(1, 80) = 5.96$, $MSE = 0.02$, $p < .05$, $\eta^2_p = .069$. This suggests that the younger participants slowed down more as a function of lag (mean difference = 293 ms) than their middle-aged counterparts (mean difference = 268 ms). Education did neither interact with lag, $F(1, 80) = 1.11$, $p > .05$, nor with age group ($F < 1$). Interestingly, however, there was a significant three-way interaction between age group, education, and lag, $F(1, 80) = 4.51$, $p < .05$, $\eta^2_p = .051$, which was only marginally significant for the log-transformed reaction times, $F(1, 80) = 3.47$, $p = .066$, $\eta^2_p = .042$. This suggests that the high-educated middle-aged participants showed a larger increase of reaction time as a function of lag than the low-educated middle-aged participants.

Zooming in on the middle-aged participants, there is a marginally significant lag by education interaction, $F(1, 38) = 3.75$, $MSE = 16,078.35$, $p = .06$, $\eta^2_p = .09$. Where the high-educated participants are at trend faster ($M = 679$ ms) than their low-educated counterparts ($M = 762$ ms) in the 1-back condition, $t = 1.70$, $p = .098$, there is no significant difference in the 2-back condition ($t < 1$).

3.2. Accuracy

Mean accuracy scores and standard errors are depicted in Fig. 2. Also shown in this figure is the mean switch cost associated with lag, which was calculated as accuracy in the 2-back condition minus accuracy in the 1-back condition. The power of the analyses was .88 for the between-groups main effects and .90 for the within-groups main effects and interactions.

Overall, the middle-aged participants were as accurate as their younger counterparts, $F(1, 80) = 1.42$, $MSE = 206.49$, $p > .05$. The low-educated participants were less accurate than the high-educated participants, $F(1, 80) = 8.93$, $p < .01$, $\eta^2_p = .10$. There was a significant main effect of condition, $F(1, 80) = 35.58$, $p < .001$, $\eta^2_p = .31$, which indicates that accuracy dropped as a function of lag.

A significant interaction between age group and lag, $F(1, 80) = 4.44$, $MSE = 204.34$, $p < .05$, $\eta^2_p = .053$, indicates

---

**Fig. 1.** Mean reaction time (ms) as a function of lag. Switch cost indicates the difference between the two lag conditions. (Error bars indicate one standard error of the mean.)

**Fig. 2.** Mean accuracy (percentage correct) as a function of lag. Switch cost indicates the difference between the two lag conditions. (Error bars indicate one standard error of the mean.)
that the middle-aged participants showed a larger accuracy drop as a function of lag than the young participants. Lag did not interact with education, however, \(F(1, 80) = 1.36, p > .05\), which suggests that switch costs were independent of educational achievement. Furthermore, age group did not interact with education \(F(1, 162) < 1\), suggesting that the age-related difference of accuracy was also independent of education. Finally, there was no significant three-way interaction between age group, education, and lag \(F(1, 162) < 1\). This means that the high-educated middle-aged participants, who showed a greater increase in response latency as a function of lag than the low-educated middle-aged participants, did not employ a different speed-accuracy tradeoff. Finally, the high-educated middle-aged participants were not significantly more accurate (79.53\% correct) than their low-educated counterparts (71.09\% correct) in the 2-back condition, \(t(38) = 1.49, p = .15\).

4. Discussion

The current experimental study was aimed at revealing possible protective effects of education on the ability of middle-aged individuals (mean age = 56.14 years) to switch focal attention in working memory. With respect to \(n\)-back performance, the results were similar to those found by Van Gerven et al. (in press) in older adults (mean age = 72.15 years). That is, reaction time did not differentially increase as a function of lag in the middle-aged compared to the younger participants. At the same time, there was a disproportionate decrease of accuracy in the middle-aged participants. Apparently, a reduced ability to switch the focus of attention in working memory is already detectable at middle age. The effect also seems to be purely attributable to aging, since our participants were carefully screened for health problems to exclude potential age-extrinsic confounds.

We acknowledge that manipulating the need to switch focal attention in the \(n\)-back task by increasing the lag beyond 1 is confounded by an increase in memory load (Verhaeghen et al., 2005). To correct for this confound, Van Gerven et al. (in press) proposed an intermediate two-digit 1-back condition. In this condition, pairs of digits were presented one after the other. The participant had to judge whether one of the digits in the current pair was the same as one of the digits in the previous pair. This supposedly bridged the gap between the 1- and 2-back conditions by merely manipulating memory load. The results corroborated the results obtained by Verhaeghen and Basak (2005): the reaction times only showed a main effect of lag, whereas accuracy revealed an age by lag interaction. This suggests that the memory confound has no significant impact on \(n\)-back performance.

Most importantly, the effect of age on switching focal attention did not interact with educational achievement, which is not in accordance with the cognitive reserve hypothesis. Furthermore, the moderating effect of education on response time suggests that the high-educated middle-aged participants show a relatively large increase of reaction time as a function of lag compared to the low-educated middle-aged participants. This seems an atypical effect in the light of the cognitive reserve hypothesis, which rather predicts a disproportionate slowing in the low-educated group. The effect may indicate, however, that the high-educated participants intentionally slowed down their responses in an attempt to maintain their level of accuracy throughout the experiment, which can be regarded as a compensatory strategy in light of the cognitive reserve hypothesis (Stern, 2002). In that case, the strategy was inadequate, however, as it did not lead to a higher level of accuracy relative to the low-educated group. Furthermore, no evidence for a differential speed-accuracy tradeoff in the high-educated middle-aged group was found, because the analysis of the accuracy scores did not reveal an inverse three-way interaction.

Alternatively, the reaction time effect may signify that the high-educated middle-aged participants are relatively slow at switching the focus of attention as compared to their low-educated counterparts, an interpretation that again challenges the cognitive reserve hypothesis. Verhaeghen and Basak (2005) did not find a disproportionate slowing in their older participants, however, at least not in the log-transformed reaction times. Van Gerven et al. (in press) did also not find such a disproportionate slowing, and neither did Leonards, Ibanez, and Giannakopoulos (2002) in a pictorial version of the \(n\)-back paradigm. Thus, age-related slowing of switching focal attention seems unlikely.

We believe that the high-educated middle-aged participants were unable to sustain their relatively high response speed across conditions. Where they responded marginally faster than their low-educated counterparts in the 1-back condition, they were equally fast in the 2-back condition. This may indicate that the compensatory effect of high education on age-related cognitive slowing (Salthouse, 1996) is confined to relatively simple task conditions, whereas it levels off if task demands are raised beyond a critical threshold (cf. Meijer, De Groot, Van Boxtel, Van Gerven, & Jolles, 2006).

In conclusion, an age-related decline of the ability to switch focal attention in working memory is already evident in middle-aged individuals. Remarkably, educational achievement does not moderate this effect. That is, education appears not to protect against an age-related decline of the ability to switch the focus of attention in working memory, which challenges the cognitive reserve hypothesis. This notion is further supported by the observation that the high-educated middle-aged participants strongly slowed down their relatively fast responses in the 1-back condition to arrive at a response speed that was comparable to that of their low-educated counterparts in the 2-back condition. We do not interpret this as a disproportionate slowing of focus switching in high-educated individuals, but rather as an inability to sustain a relatively high response speed across conditions, which again rivals the cognitive reserve hypothesis. Thus, our results suggest that the cogni-
tive reserve hypothesis is not applicable to all cognitive control functions. It also adds to the growing body of evidence that the protective effect of education, if existent at all, is rather limited (for a critical overview, see Christensen et al., 2007). Systematically testing the reserve hypothesis against a broader range of functions may further delineate the “protective reach” of education and other estimates of cognitive reserve.

References


