Comparing Age Effects in Normally and Extremely Highly Educated and Intellectually Engaged 65 - 80 Year-olds: potential Protection from Deficit through Educational and Intellectual Activities across the Lifespan

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Abstract

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Title: Comparing Age Effects in Normally and Extremely Highly Educated and Intellectually Engaged 65 - 80 Year-olds: Potential Protection from Deficit through Educational and Intellectual Activities across the Lifespan.

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Abstract

Education and cognitive activity have been suggested to protect against cognitive decline in old age. However, little is known about the long-term effects of extremely high levels of education and intellectual activity across the lifespan. The present study investigated the extent to which these two variables may moderate the age-related differences in cognitive performance in old adults. Therefore, story recall, paired-associates learning, reading span and letter digit performance of 62 university professors (mean age = 72.47) were compared with those of a representative sample of 196 participants of the Zurich Longitudinal Study of Cognitive Aging (mean age = 73.04). The results demonstrate that the highly educated sample performed significantly better than the normally educated sample in the paired-associates learning and reading span test. Furthermore, age effects were found in the letter digit as well as in the paired-associates learning test. While the normally educated sample demonstrated an age-related decrease in the paired-associates learning test, the performance of the highly educated sample actually increased with increasing age. These findings suggest that extremely high levels of education and intellectual activity may postpone age-related deficits in paired-associates learning tasks, but not in speed of processing tasks.

Key Words

Education • protection factor • cognitive performance • typical intellectual engagement
Introduction

Average age differences and longitudinal age changes in cognitive development are well documented (for an overview see [1]). However, relatively little research exists on protective factors against cognitive decline in old age. Among the factors most prominently mentioned as potentially protective are education, intellectual engagement, and lifelong learning [2]. In fact, Stern [3] even suggested that through education and intellectual engagement people can build up cognitive reserve to buffer brain pathology or brain lesions. This explains why people with higher levels of intelligence, higher education and greater vocational success are more likely to recover from a brain lesion (cf. [4]). However, it is still unclear under which circumstances and to what degree education and intellectual activity influence the developmental trajectories of cognitive abilities in old age.

The literature on education and its influence on cognitive development in old age is inconsistent. Some studies have found a positive effect of education on cognitive development (cf. [5, 6]) whereas others have not [7]. Further studies have emphasized that education has only a protective effect on certain cognitive abilities, namely the verbal abilities [7, 8]. One reason for these equivocal findings may be the samples examined. For instance, whereas Hultsch, Hertzog, Small, and Dixon [6] compared 487 community-dwelling adults aged between 55 and 86 (first measurement), Christensen, Henderson, Griffiths and Levings [7] examined 26 fellows of the Australian Academy of Humanities, Academy of Social Sciences and Academy of Science (mean age 75.8), 30 retired blue-collar workers (mean age 74.5) and 30 Ph.D. students from the Australian National University. Another reason for the equivocal findings may be the difficulty of controlling for similarity in lifestyles and intellectual activity. Typically, representative samples contain large interindividual differences in education, intellectual activities, social status or income.

Our study focuses on the behavioral cognitive plasticity in old age [2]. We assume that very high levels of education and lifelong intellectual engagement may postpone average
age-related changes in cognition and, thus, would predict smaller age differences compared to a less well-educated sample. Therefore, we compared age differences in an extremely well-educated sample of individuals typically highly engaged in intellectual activities throughout their lives, i.e., university professors, to age differences in a representative sample of old individuals covering the same age range.

Previous studies with professor samples conducted group comparisons of cognitive performance in an active, non-active or a combined sample of active and retired professors and normal comparison samples. They have consistently demonstrated an advantage of the well-educated professor samples in the encoding and retrieval of verbal material [9-12]. However, in extension of these findings, if extremely high levels of education and intellectual engagement protects from cognitive decline, cross-sectional data should demonstrate smaller age-related differences in the professor compared to a normal comparison sample.

Therefore, in the present study we examined professors from their retirement year onward (age range 65 to 80 years). As a comparison sample, the data of a representative sample of 65-80-year-olds was used [13]. To assess if education has a positive effect on cognitive aging, we compared groups with respect to performance and age effects in cognitive measures typically found to be age sensitive, i.e. processing speed, working memory and cued and free recall [14].

Methods

Sample

In our study, we compared two samples, a representative and a highly educated professors’ sample. The representative sample consisted of participants from the Zurich Longitudinal Study of Cognitive Aging (ZULU) [13] designed to be representative of older adults living in Switzerland. The participants of the highly educated sample were recruited on the basis of a complete list of all University of Zurich professors born after 1910 who had
reached retirement age. To match the participants according to their age and gender, only male participants between the ages of 65 and 80 years were included in the analysis. Thus, the normally educated sample consisted of 196 participants (out of 364) and the highly educated sample of 62 participants (out of 86). When screened for dementia (Mini-Mental State Examination (MMSE) [15]), no participant from the highly educated sample was at risk for dementia (threshold value 26), whereas two participants in the normally educated sample were (threshold value 24) [16]. Those two were removed from the data analysis.

**Materials and Procedure**

All participants, except one with a walking disability (who was tested at home), attended the test session at a centrally located testing site after signing the informed consent form. All participants were instructed and tested individually. Before starting the actual experiment, participants filled out questionnaires on sociodemographic information, the MMSE, subjective health, and on their typical intellectual engagement (TIE; see below). Then each participant completed a cognitive test session lasting approximately 40 minutes, including story recall, paired-associates learning, a reading span task and a letter digit substitution test, all of which were computerized except for the story recall.

In our study, intellectual engagement was measured with the Typical Intellectual Engagement questionnaire (TIE) adapted from Dellenbach and Zimprich [17]. The instrument uses 17 items to measure the degree to which individuals prefer to engage in cognitively demanding or challenging leisure tasks and activities. It has a minimal score of 17 and a maximum score of 85 points, with a higher score implying that the person likes to be engaged in challenging leisure tasks. In our study Cronbach’s alpha was between 0.58 and 0.81.

To measure episodic memory, story A of the Logical Memory subtest of the German version of the Wechsler Memory Scale-Revised (WMS-R) [18] was used. In this test, participants are instructed to listen closely to a story read aloud by the experimenter. Then
the participants are asked to recall as many of the 25 semantically meaningful units as possible. Test-retest reliability of this test is .79 [18].

The paired-associates learning task consisted of 12 semantically unrelated word pairs of the German WMS-R and the Munich Verbal Memory Test (MVGT) [19]. After presentation of all 12 word pairs, only the first word of a pair appeared on the screen as a cue, and the second was replaced by a question mark (e.g., salad - ?), using a different order than that used during encoding. For each cue presented, participants were asked to recall the associated target word. Test-retest reliability for the WMS-R is .78 [18].

To assess working memory, a modified version of the reading span task by Daneman and Carpenter [20] was utilized. In this test, participants are asked to read sentences aloud and to decide if the sentence was meaningful or not by pressing designated keys on the computer keyboard. Furthermore, participants were instructed to memorize the last word of each sentence. After several sentences, three question marks appeared on the screen, indicating that the participant should name the memorized words in the same order as they had been presented. The dependent variable was the average percentage of items recalled in correct order [21], and test-retest reliability is .76 [22].

Finally, participants had to perform a letter digit substitution task which was similar to the well-known Digit Symbol Substitution task, except that participants were required to assign digits to letters instead of symbols to digits [23]. For each item, there was a different coding table and a new cue letter in order to reduce memory influences [23]. After two practice items, participants had 90 seconds to work on the task. Test-retest reliability is .88 [24]. All cognitive tests used in our study are described in more detail in Zimprich et al. [13].

Statistics

The Kolmogorov-Smirnov test revealed that while the test results in the paired-associates learning test were nonparametric they were parametric in all the other cognitive tests. Differences in the mean values of the different cognitive tests were either assessed by t-
test (parametric data) or by Mann-Whitney U test (nonparametric data). To consider the sample differences concerning the principle variables, the Hotelling’s $T^2$ was utilized. Furthermore, to locate age effects in the two samples, either Pearson correlations (parametric data) or Spearman correlations (nonparametric data) were performed. To test whether the correlations differed significantly between the two groups, Fisher’s $z$-transformation was utilized.

**Results**

Table 1 presents the mean values and the standard deviations for the sociodemographic variables, subjective health, typical intellectual engagement, and cognitive test scores of the highly educated and normally educated samples. As expected, the groups did differ in their formal education, typical intellectual engagement and income, but not in their subjective health and age (see Table 1).

Independent-sample $t$-tests and Mann-Whitney U tests were conducted to compare the test results in story recall, paired associates, the reading span task and the letter digit substitution test in the normally and highly educated sample. While the highly educated participants performed on average significantly better in the paired associates ($z = -2.55, p < 0.05, r = 0.40$) and the reading span tasks ($t(256) = 7.82, p < 0.001, d = 1.14$) than the normally educated participants, this was not the case in the story recall ($t(256) = 0.07, d = 0.01$) and the letter digit substitution tests ($t(256) = 0.11, d = 0.02$). Furthermore, to consider the differences of the means between the two samples, a Hotelling’s $T^2$-test ($F(4, 253) = 16.02, p < 0.001$) demonstrated that overall the means of the two samples were not equal.

To test the hypothesis whether very high levels of education and lifelong intellectual engagement may eliminate average age-related differences in cognition, we calculated correlations between age and the different cognitive tests within the two samples. As illustrated in Table 2, in both samples there was no significant relation between age and story recall and age and the reading span task. However, a lower performance in the letter digit
substitution test was associated with higher age in both samples. Higher age was significantly related to lower performance in the paired-associates learning test only in the normally educated sample. In contrast, in the highly educated sample, there was a tendency for age to be positively correlated with performance in paired-associates learning. Furthermore, we used a Fisher’s z-transformation to test whether the correlations of age and paired-associates learning differed significantly between the two samples. The results demonstrated that there is a significant difference between the correlations between the samples ($z = 3.07, p < 0.01$).

Based on these results, it cannot be established that the better performance in paired-associates learning of the highly educated samples was more likely due to a longer maintenance of the cognitive ability or to a higher starting level. If, however, the younger participants of the highly educated sample had the same starting level in the paired-associates learning test as the younger participants in the normally educated sample, this would suggest that individuals in the highly educated sample might be resistant to age effects for a longer time, but not that high education per se would lead to an increase in paired-associates scores. To answer this question, we split both samples into two age groups. Thus the cognitive test scores of the 65- to 72-year-olds of the normally educated sample were compared to the test scores of the 65- to 72-year-olds of the highly educated sample, and the same was done with the 73- to 80-year-olds. The results demonstrated that while the test score in the paired-associates learning test did not differ significantly between the 65- to 72-year-old adults of the normally and highly educated sample ($z = -0.32, r = 0.01$), they did differ between the 73- and 80-year-olds ($z = -3.14, p < 0.01, r = 0.88$). This is an indication that the effects of extremely high levels of education only appear in older ages. Concerning the other cognitive tests, the effects remained stable over the different age groups, i.e., when there was no difference in the means of the test results between the younger age groups of the normally and highly educated sample, there was also no difference to be found in the older age groups of the two samples (story recall, letter digit substitution test) and when there was a difference
between the two samples (reading span task) there was also a difference to be found in the older age groups of the two samples.

Table 1. Means and Standard Deviations of sociodemographics, health, and cognitive test performances

<table>
<thead>
<tr>
<th>Variable</th>
<th>High education sample (N = 62)</th>
<th>Normal education sample (N = 196)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Age</td>
<td>72.47</td>
<td>±4.02</td>
</tr>
<tr>
<td>Subjective health</td>
<td>5.03</td>
<td>±0.72</td>
</tr>
<tr>
<td>Income*</td>
<td>6.97</td>
<td>±0.18</td>
</tr>
<tr>
<td>Education and TIE score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education (years)</td>
<td>20.61</td>
<td>±2.26</td>
</tr>
<tr>
<td>TIE sum score</td>
<td>66.58</td>
<td>±6.38</td>
</tr>
<tr>
<td>Cognitive Tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Story recall</td>
<td>14.26</td>
<td>±3.47</td>
</tr>
<tr>
<td>Paired-associates learning</td>
<td>3.81</td>
<td>±2.86</td>
</tr>
<tr>
<td>Reading span</td>
<td>0.77</td>
<td>±0.14</td>
</tr>
<tr>
<td>Letter digit</td>
<td>33.10</td>
<td>±5.92</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001

*1 < 2000 CHF, 2 = 2000CHF - 3000CHF, 3 = 3000CHF - 4000CHF, 4 = 4000CHF - 6000CHF, 5 = 6000CHF - 8000CHF, 6 = 8000CHF - 10000CHF, 7 > 10000CHF

Table 2. Correlations of cognitive test scores with age

<table>
<thead>
<tr>
<th>Cognitive tests</th>
<th>High education sample (N = 62) x age</th>
<th>Normal education sample (N = 196) x age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Story recall</td>
<td>-0.11</td>
<td>-0.08</td>
</tr>
<tr>
<td>Paired-associates learning</td>
<td>0.18</td>
<td>-0.27**</td>
</tr>
<tr>
<td>Reading span</td>
<td>0.03</td>
<td>0.00</td>
</tr>
<tr>
<td>Letter digit</td>
<td>-0.41**</td>
<td>-0.34**</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001
Discussion
The main goal of this study was to compare the age differences in cognitive performance in a sample of normally and a sample of highly educated older adults. First of all, our results replicate earlier findings that highly educated adults tend to outperform normally educated adults in verbal tasks. It has to be noticed, however, that in our study this is only the case for two verbal tasks out of three, namely paired-associates learning and reading span. Furthermore, when the samples were stratified for age, the sample differences in the paired-associates learning test disappeared between the 65- to 72-year-olds. This suggests that the advantages of extremely high levels of education may only start to appear in older age. In contrast, in the working memory task extremely high level of education was related to better performance across the complete age range.

It has to be noted that a lack of sample differences may be due to a particularly high performance comparison sample. For instance, in our study normally educated adults performed equally well as highly educated adults when they had to recall a story. This is different from the findings of Shimamura, Berry, Mangels, Rusting, and Jurica [10], who did the same story recall test with an American sample. While in their study the professors retrieved approximately 54 percent of the story and the non-professors 42.5, in our study the highly educated sample recalled 57 percent in contrast to 55.7 percent of the normally educated sample.

In any case, the main goal of our study was to test whether very high levels of education may reduce average age-related differences in cognition. There was an age effect for the speed measure of letter digit substitution, but no difference in the age effect between the samples. The age effect is not surprising, since speed is one of the most age sensitive variables (cf. [25]), and education may have only a small influence on its developmental trajectory. The age effect on speed of processing has also been demonstrated in other studies with a professor sample (cf. [10, 11]). There were no age effects for verbal working memory
and verbal memory (except in the paired-associates learning test), and no differences in the age effects between the groups. On the one hand this is good news, because it suggests a stable level of essential memory performances even in normally educated samples. On the other hand, it is difficult to interpret without a longitudinal follow-up. Since we have used cognitive performance measures that have reliably shown age effects, but did not observe age associated deficits, it is unclear why this is the case. It is unlikely that the lack of age effects is due to selection effects, because then we should have found no age-related differences in speed. It might be the case that education only emerges as a predictor with performance dropping below a certain threshold, or that intellectual engagement can help to compensate for declines in both samples, or that the normal samples had a higher level of intellectual engagement compensating for lower levels of education.

Most interestingly, there was an age effect in the normally educated adults in the paired-associates learning task, but not in the highly educated adults. Although the younger adults in both samples had the same starting level in this cognitive task, there was a significant difference in the older adults. This suggests that while age had an effect on the test score in the normally educated sample, the test results of the highly educated sample stayed unaffected of age. On the one hand, this finding suggests that education may protect from age-associated deficits specifically in paired-associates learning. On the other hand, the results also suggest that education may not make immune against age deficits, but that it postpones the processes eventually leading to these deficits. Only longitudinal data will make it possible to determine the influence of extremely high levels of education on the development of paired-associates learning, but the current cross-sectional data do reveal that the highly educated adults tend to have some kind of educational benefit that affects the age correlated deficits in the paired-associates learning task positively.

Overall, this study presents an important overview on cognitive abilities of 65- to 80-year-olds. It must be noted that comparing extremely highly educated aged individuals with
representative samples of old adults allows us to examine age effects in old age that are not distorted by cohort differences in education and lifestyle. However, such a selection of samples can cause problems. The data cannot easily be generalized to the general population. Moreover, due to the research design, a self-selection may have taken place even within the professors’ sample so that they might be even more selective with respect to health and motivation to participate. Notwithstanding, the findings of our study indicate that some deficits, which were hitherto associated with chronological age, are more likely a result of other influences or occur under certain circumstances only in very old age. The data suggests that education and lifelong intellectual engagement can influence test performance to such an extent that age deficits in paired-associates learning might completely disappear in 65- to 80-year-olds. If it is not age which most influences cognitive development, it might be possible to influence the process of cognitive development more than initially thought. Whether this is truly the case or not, however, can only be determined by conducting longitudinal follow-up studies which consider the individual development of cognitive abilities and examine the role of self-selection in the study on the effects of education and intellectual engagement on cognitive aging. When these data are available and demonstrate promising results, the next step will be to investigate suitable trainings and interventions to minimize the difference of the cognitive age deficits between highly and normally educated adults.

Acknowledgement

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References


