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## Education Does Not Slow Cognitive Decline with Aging: 12-Year Evidence from the Victoria Longitudinal Study

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### Abstract

Although the relationship between education and cognitive status is well-known, evidence regarding whether education moderates the trajectory of cognitive change in late life is conflicting. Early studies suggested that higher levels of education attenuate cognitive decline. More recent studies using improved longitudinal methods have not found that education moderates decline. Few studies have explored whether education exerts different effects on longitudinal changes within different cognitive domains. In the present study, we analyzed data from 1,023 participants in the Victoria Longitudinal Study to examine the effects of education on composite scores reflecting verbal processing speed, working memory, verbal fluency, and verbal episodic memory. Using linear growth models adjusted for age at enrollment (range: 55–94) and gender, we found that years of education (range: 6–20) was strongly related to cognitive level in all domains, particularly verbal fluency. However, education was not related to rates of change over time for any cognitive domain. Results were similar in individuals older or younger than 70 at baseline, and when education was dichotomized to reflect high or low attainment. In this large longitudinal cohort, education was related to cognitive performance but unrelated to cognitive decline, supporting the hypothesis of passive cognitive reserve with aging.

### Keywords

cognitive reserve; processing speed; working memory; verbal fluency; verbal episodic memory

## Introduction

The hypothesis of cognitive reserve asserts that older individuals with greater experiential resources exhibit better cognitive functioning and are able to tolerate higher levels of brain pathology before displaying clinical symptoms (Stern, Alexander, Prohovnik, & Mayeux, 1992; Scarmeas & Stern, 2004). One of the most well-established proxy measures of reserve capacity in the elderly is educational attainment, which is thought to reflect more effective use of brain networks or cognitive paradigms (Stern, 2009). In line with the hypothesis of cognitive reserve, many studies in both North America and Europe have suggested that educational attainment is associated with better cognitive performance and reduced risk for cognitive impairment and dementia in late life (Stern, 2007; Brayne & Calloway, 1990; De Ronchi et al., 1998; Evans et al., 1997; Fratiglioni et al., 1991; Gatz et al., 2001; Katzman, 1993; Launer et al., 1993; Mortel et al., 1995; Prencipe et al., 1996; Raiha et al., 1998; Stern et al., 1994).

Results with respect to whether educational attainment moderates the trajectory of age-related cognitive decline have been mixed (Antsey & Christensen, 2000). Several studies reported that educational attainment attenuates cognitive decline in samples of non-demented, older adults (Bosma, et al., 2003; Lyketsos, Chen, & Anthony, 1999; Evans et al., 1993; Farmer et al., 1995; Butler, Ashford, & Snowdon, 1996; Albert et al., 1995; Arbuckle et al., 1998). Such results support an *active cognitive reserve* hypothesis in which education promotes more efficient cognitive processing and use of brain networks, which results in smaller cognitive declines in the face of neuropathology, effectively *slowing* the process of age-related cognitive decline (Stern, 2002).

These findings have been challenged by several subsequent studies that employed more sophisticated statistical methodologies (Tucker-Drob, Johnson, & Jones, 2009; Christensen, et al., 2001; Glymour et al., 2005; Karlamangla et al., 2009; Van Dijk et al., 2008; Wilson et al., 2009). These reports support a *passive cognitive reserve* hypothesis, in which individuals with greater educational attainment continue to perform at a higher level than similarly aged individuals with less education, but decline at a similar rate (Stern, 2002). Still other studies have found that educational attainment accelerated cognitive decline in populations with confirmed Alzheimer's disease (Anel, Vigen, Mack, Clark, & Gatz, 2006; Stern, Albert, Tang, & Tsai, 1999). These results may support a *compensation* hypothesis, in which intact domains compensate for declines in other cognitive abilities until they, too, begin to deteriorate, leading the way for more rapid decline (Christensen et al., 1997; Reuter-Lorenz & Mikels, 2006).

One potential explanation for these discrepant findings is that education may exert different effects on the trajectories of different cognitive domains. For example, Alley et al. (2007) used growth curve modeling to show that higher levels of education attenuated decline in overall global cognition, accelerated decline in verbal memory, and were unrelated to decline in working memory. Taken together, the aforementioned studies demonstrate that the effects of education on the rate of cognitive aging have not yet been fully established. The present study sought to contribute to this highly conflicting literature by examining the influence of educational attainment on trajectories of four cognitive abilities (i.e., processing speed, working memory, verbal fluency, and verbal episodic memory) over 12 years in a large sample of initially healthy, community-dwelling older adults who participated in the Victoria Longitudinal Study (VLS).

## Method

### Participants

The VLS included adult residents of greater Victoria, British Columbia between 55 and 85 years of age without serious health conditions who were community-dwelling at study entry. Following a longitudinal-sequential research design, participants were followed up at approximate 3-year intervals (see Dixon & De Frias, 2004 for a description of the design and measures of the VLS). The present study included data available from 1,023 Caucasian individuals from VLS Sample 1 (N=487; waves 1–5; >12 years follow-up) and Sample 2 (N=536; Waves 1–3; >6 years follow-up). Sample 1 comprised a greater proportion of males (41% vs. 33%;  $\chi^2(1)=6.39$ ;  $p=.01$ ) and evidenced a lower level of education, on average (13.4 vs. 14.7 years;  $t(998)=-7.02$ ;  $p<.001$ ). There were no significant differences between Samples 1 and 2 with regard to age at study entry. As previously reported, the average retention rate across all waves was over 70%, and participants who returned for follow-up testing were positively selected with regard to demographics, self-reported health, and cognitive status (Hultsch, Hertzog, Dixon, & Small, 1998).

### Independent variables

Age, gender and education, as years of completed schooling, were self-reported at baseline. Education values greater than 20 were top-coded as 20, reflecting completion of a doctoral degree. In primary models, we considered education as a continuous variable. In supplementary models, we examined results dichotomizing education at 13 or fewer years versus 14+ years, as 13 years represents the equivalent of high-school completion for students in Central/Eastern Canada. Finally, we considered an alternative indicator of cognitive reserve (i.e., literacy) with a vocabulary test completed at the baseline occasion (Hultsch et al., 1998). In supplementary models, performance on this vocabulary test was included as a continuous primary predictor, instead of education.

### Cognitive outcomes

Composite scores were created for each cognitive domain of interest. Previous studies of VLS data have employed similarly constructed composites to index verbal processing speed and episodic memory based on confirmatory factor analysis (Small, Dixon, McArdle & Grimm, 2011; Hertzog, Dixon, Hultsch, & MacDonald, 2003). Briefly, the verbal processing speed composite comprised two tests: lexical decision (speeded word/non-word; Baddeley, Logie, & Nimmo-Smith, 1985) and sentence verification (speeded plausible/implausible sentence; Palmer, MacLeod, Hunt, & Davidson, 1985). The working memory composite comprised three tests: sentence construction (Hultsch et al., 1998) and two span tests (listening and computation; Salthouse & Babcock, 1991). The verbal fluency composite comprised three written fluency tests from the Kit of Factor Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976): controlled associates, opposites, and figures of speech. The verbal episodic memory composite comprised delayed recall scores from two word list learning and two story memory tasks (Dixon et al., 2004). For all measures, raw scores were standardized to z-score metric using means and standard deviations derived from baseline scores on the respective test. Composite scores were computed by averaging standardized scores on the tests within each domain.

### Statistical Analyses

Modeling was carried out using Mplus 6.0 maximum likelihood (MLR) estimation and full information maximum likelihood (FIML) to handle missing data. First, unconditional growth models were built in which the linear and quadratic effects of time were examined separately for each of the four cognitive composites. Nested model comparisons using the

chi square test were used to evaluate whether including quadratic time improved model fit. Next, age at baseline (centered at age 70), self-reported education at baseline (in years), and gender were added to the model as continuous (age and education) or dichotomous (gender) variables. As described above, we also examined supplemental models in which education was either dichotomized to reflect high and low attainment or replaced with a baseline vocabulary measure. We also examined primary models separately for younger (<70 years) and older ( $\geq 70$ ) participants. In all models, time was parameterized with time scores representing years since study entry. All models were estimated with random intercepts and random slopes for time.

## Results

The sample comprised 650 females and 373 males who ranged in age from 54 to 94 years at baseline (mean=68.9 years; SD=6.9). Participants reported attaining 6 to 20 years of education (mean=14.1 years; SD=3.1). There was a significant negative correlation between age and educational attainment ( $r=-.117$ ;  $p<.001$ ). Compared to women, men reported significantly higher levels of education ( $t(683.420)=-3.343$ ;  $p=.001$ ), on average. There was no difference in age at study entry between men and women.

### Unconditional growth models

Unconditional models for each composite containing only linear slopes were compared to corresponding models with both linear and quadratic slopes. For verbal fluency, verbal episodic memory and working memory, models that included both fixed and random effects of a quadratic slope did not converge. Thus, the model used in nested model comparisons for these three domains included only quadratic fixed effects. Adding quadratic change failed to improve model fit for any of these three cognitive domains. Thus, subsequent models included only linear slopes for verbal fluency, verbal episodic memory, and working memory. For processing speed, including a quadratic slope improved model fit ( $\Delta\chi^2(4)=-43.884$ ,  $p<.001$ ).

As shown in Table 1, significant linear decline over time was evident for verbal fluency, verbal episodic memory, and working memory. Comparing across domains, scores declined about 2–4% of one standard deviation (SD) per year. The fastest decline (3.5% SD per year) occurred in the working memory domain, and the slowest decline (1.5% SD per year) occurred in the verbal fluency domain. Significant positive quadratic (U-shaped) change was evident for processing speed, indicating slight improvements in speed (lower scores) between the first and second assessment waves, but slowing of performance (higher scores) thereafter. There was significant individual variation in cognitive ability in all four domains at baseline. Random effects in slopes were significant for working memory ( $p=.011$ ) and verbal episodic memory ( $p<.001$ ). Intercepts and slopes were not significantly correlated within any domain.

### Effects of age, gender, and education on cognitive performance and decline

Next, the three independent variables were added to the best-fitting models described above. The conditional model for processing speed would not converge without constraining the random variance of the quadratic slope to 0. In order to obtain estimates of the effects of interest (i.e., regression paths between the independent variables and cognitive change), the quadratic slope was removed from the model. It should be noted that the fixed effect of the linear slope in the unconditional model that did not include the quadratic slope was positive and significant (0.029;  $p<.001$ ), which reflects increasing scores (slowing) of approximately 3% SD per year.

Older age at baseline was associated with worse cognitive performance in all four domains (Table 2). Age appeared to exert the greatest effect on processing speed, as each year of age greater than 70 reduced performance by nearly 5% SD. Age appeared to exert the smallest effect on verbal fluency, as each year of age greater than 70 reduced performance by only 2.3% SD. Older age was also associated with accelerated decline in all four domains.

Controlling for baseline age, gender was not associated with cognitive performance in processing speed, working memory, or verbal fluency. Gender was associated with poorer verbal episodic memory such that males performed approximately 1/3 SD worse on this composite, as compared to females. Gender was unrelated to the rate of decline in any domain.

Controlling for baseline age and gender, higher education was associated with better performance in all four cognitive domains. This beneficial effect of education appeared to be greatest in the verbal fluency domain, for which each year of education was associated with higher scores of nearly 11% SD. The influence of education on cognitive performance was smallest for the processing speed domain, for which each year of education was associated with higher scores of only 3.7% SD. Education was unrelated to the rate of decline in any domain, which can be visualized as parallel model-predicted trajectories in Figure 1. The pattern of results did not change when the education variable was dichotomized at the sample median or split into tertiles (Table 3).

Because younger individuals in the present sample reported higher levels of education than did older individuals, we examined the possibility that cohort effects masked association between education and cognitive decline. First, we ran all four conditional models excluding the covariate of baseline age. We also ran these models separately in subgroups of younger (<70 years) and older ( $\geq 70$  years) adults. In all cases, we failed to find an association between education and change on any of the cognitive composites (Table 3). We also explored the potential for an alternative indicator of cognitive reserve (literacy) to moderate cognitive decline. We ran the four conditional models using scores on the vocabulary test at baseline in place of the education variable and found no differences in the pattern of results. That is, baseline vocabulary was positively associated with intercepts in all four conditional models, but unrelated to slopes.

## Discussion

The present study contributes to the debate regarding a potential influence of educational attainment on the trajectory of cognitive aging by reporting results from longitudinal analyses featuring (a) multiple cognitive domains over (b) a long-term follow-up period (i.e., 12 years) for (c) a large sample covering a broad, 40-year band of older adults. In this Canadian sample, education was related to the cognitive abilities of processing speed, working memory, verbal fluency and verbal episodic memory, but we did not find evidence that educational attainment moderates declines in any of these domains. These results support a passive cognitive reserve hypothesis, in which individuals with greater educational attainment continue to perform at a higher level compared to similarly aged individuals with less education, but decline at a similar rate (Stern, 2002).

These findings are consistent with and extend several recent studies that observed no moderating effect of education on cognitive decline with aging. Applying longitudinal structural equation modeling to data obtained through the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study, Tucker-Drob and colleagues (2009) reported that education did not moderate the trajectories of reasoning or processing speed over a five-year period. Using both latent growth curve models and more traditional

regression, Christensen et al. (2001) found that education was not related to change in crystallized intelligence, memory, cognitive speed, or global cognition over 8 years in the Canberra longitudinal study. Reporting 6-year follow-up data from the Maastricht aging study, Van Dijk et al. (2008) reported no significant time by education interaction for individual cognitive tests assessing learning and memory, interference control, set shifting, fluency, mental speed, or global cognition.

Some studies suggesting a moderating effect of education on cognitive aging (e.g., Bosma et al., 2003) have tested the probability of cognitive impairment given varying levels of education but did not examine cognitive trajectories per se. Thus, results such as those of Bosma et al. (2003) are also consistent with a passive cognitive reserve hypothesis in which individuals with greater reserve consistently perform better and therefore take longer to reach an impaired performance level.

Importantly, many previous studies adjusted for baseline performance in their analyses, which could account for positive results. In one review of longitudinal studies of education and cognitive change, 12 of the 14 available studies reported a benefit of education (Antsey & Christensen, 2000). Of these, eight studies had explicitly conditioned on baseline performance. Recent papers have empirically examined the consequences of baseline adjustment in longitudinal research and have concluded that conditioning on the baseline measure produces biased effect estimates and the potential for spurious correlations between an exposure variable (e.g., education) and change on a measure if the exposure variable predicts baseline level of the measure (Glymour et al., 2005; Dugravot et al., 2009). Because of the strong relationship between education and baseline cognitive status in the present study and other longitudinal studies of cognitive aging, it is likely that many previous studies linking educational attainment to slowed cognitive decline suffered from this statistical artifact. Additionally, when cognitive assessments with low reliability are used, this bias can be much larger than any plausible causal effect of education on rate of cognitive change (Yanez, Kronmal, & Shemanski, 1998). Our study advances on prior work by carefully modeling cognitive performance with composites rather than individual tests to improve measurement reliability, using unbiased longitudinal growth models, evaluating long-term cognitive changes, and demonstrating the consistency of results across theoretically distinct cognitive domains.

A limitation of the present studies lies in the relatively high mean educational attainment in the sample. Lyketsos et al. (1999) have highlighted the general lack of understanding regarding a potential incremental association between education and cognitive decline. They assert that individuals with the lowest levels of education may experience the greatest declines, whereas additional education beyond 9 years may not confer further attenuation of decline. Because the present sample included only a very small subset of individuals (3%) with fewer than 9 years of education, we were unable to fully evaluate this issue. However, the pattern of results did not change when the education variable was dichotomized at the sample median or split into tertiles. From these data, we can conclude that in this relatively well-educated sample (mean = 14.1 years), years of education did not appear to moderate cognitive trajectories. Future studies are needed to more fully examine the possibility of steeper decline among older adults with very low educational attainment.

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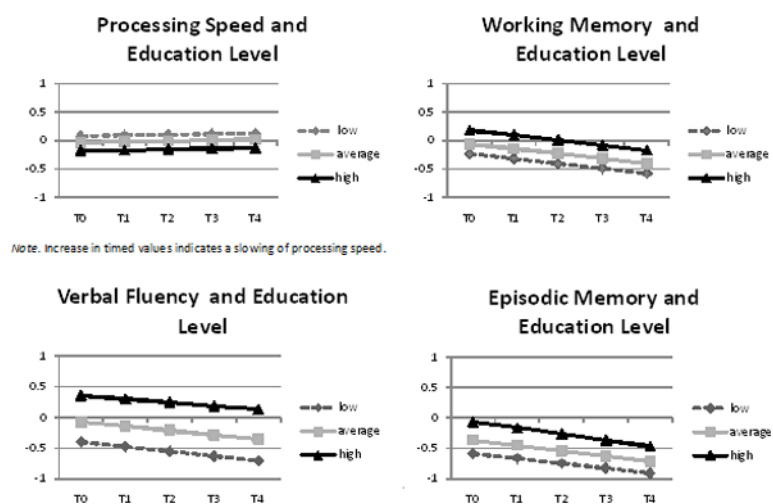


Figure 1.

**Table 1**

Fixed effects from the four separate unconditional growth models

<b>Domain</b>	<b>Estimate</b>	<b>SE</b>	<b>p</b>
Processing speed			
Intercept/baseline score	−0.014	0.030	.644
Linear annual rate of change	−0.011	0.008	.146
Quadratic annual rate of change	0.003	0.000	<.001
Working memory			
Intercept/baseline score	0.039	0.029	.182
Linear annual rate of change	−0.035	0.004	<.001
Verbal fluency			
Intercept/baseline score	0.028	0.026	.282
Linear annual rate of change	−0.015	0.003	<.001
Verbal episodic memory			
Intercept/baseline score	0.027	0.026	.312
Linear annual rate of change	−0.028	0.003	<.001

Table 2

Covariate effects in the four separate conditional models

Domain	Intercept/baseline score			Annual rate of change		
	Estimate	SE	p	Estimate	SE	p
Processing speed						
Age	0.048	0.005	<.001	0.004	0.001	<.001
Gender	−0.029	0.054	.595	0.003	0.006	.674
Education	−0.037	0.009	.001	0.000	0.001	.649
Working memory						
Age	−0.036	0.004	<.001	−0.001	0.000	.002
Gender	−0.025	0.057	.654	0.008	0.006	.184
Education	0.059	0.009	<.001	0.000	0.001	.984
Verbal fluency						
Age	−0.023	0.003	<.001	−0.002	0.000	<.001
Gender	−0.066	0.048	.163	−0.003	0.005	.451
Education	0.108	0.007	<.001	0.001	0.001	.251
Verbal episodic memory						
Age	−0.042	0.004	<.001	−0.003	0.000	<.001
Gender	−0.331	0.049	<.001	0.004	0.005	.411
Education	0.075	0.008	<.001	−0.001	0.001	.358

**Table 3**

Effects of education (or literacy) on linear slopes in the supplementary models

Model	Processing speed			Working memory			Verbal fluency			Verbal episodic memory		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Dichotomized	0.004	0.006	.508	0.002	0.006	.704	0.008	0.005	.103	-0.005	0.005	.375
Trichotomized	0.001	0.004	.854	0.001	0.004	.806	0.006	0.003	.064	-0.006	0.004	.116
Older ( $\geq 70$ ) cohort	0.001	0.004	.853	0.000	0.002	.865	0.001	0.002	.478	-0.002	0.002	.327
Younger ( $< 70$ ) cohort	0.000	0.001	.975	0.000	0.001	.663	0.001	0.001	.352	0.000	0.001	.624
Literacy	0.000	0.000	.517	0.000	0.000	.788	0.000	0.000	.666	0.001	0.000	.117