Frequent Cognitive Activity Compensates for Education Differences in Episodic Memory

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Objectives: *To test the hypothesis that frequent participation in cognitive activities can moderate the effects of limited education on cognitive functioning.* **Design:** *A national study of adult development and aging, Midlife in the United States, with assessments conducted at the second wave of measurement in 2004–2006.* **Setting:** *Assessments were made over the telephone (cognitive measures) and in a mail questionnaire (demographic variables, measures of cognitive and physical activity, and self-rated health).* **Participants:** *A total of 3,343 men and women between the ages of 32 and 84 with a mean age of 55.99 years.* **Measurements:** *The dependent variables were Episodic Memory (Immediate and Delayed Word List Recall) and Executive Functioning (Category Fluency, Backward Digit Span, Backward Counting Speed, Reasoning, and Attention Switching Speed). The independent variables were years of education and frequency of cognitive activity (reading, writing, doing word games or puzzles, and attending lectures). The covariates were age, sex, self-rated health, income, and frequency of physical activity.* **Results:** *The two cognitive measures were regressed on education, cognitive activity frequency, and their interaction, while controlling for the covariates. Education and cognitive activity were significantly correlated with both cognitive abilities. The interaction of education and cognitive activity was significant for episodic memory but not for executive functioning.* **Conclusion:** *Those with lower education had lower cognitive functioning, but this was qualified by level of cognitive activity. For those with lower education, engaging frequently in cognitive activities showed significant compensatory benefits for episodic memory, which has promise for reducing social disparities in cognitive aging.* (Am J Geriatr Psychiatry 2010; 18:4–10)

Key Words: Cognitive activity, education, memory, executive function, cognitive aging

Education differences are a key source of social disparities and variability in cognitive functioning.[1] Higher levels of education are tied to higher cognitive functioning throughout adulthood[2–5] and a lower risk for dementia.[6–12] One possible mechanism whereby the long-term effects of higher education

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for cognition could be realized is that those with higher education have advantages and resources that allow them to engage more often in cognitively challenging activities.[13–15]

There is evidence that engaging in frequent cognitive activities results in improved cognitive performance.[16–21] For example, in a recent review, interventions using cognitive exercises were found to have strong effects on improving cognitive performance.[22] Moreover, high levels of work complexity involving mental stimulation during midlife were found to decrease the risk of dementia in later life.[23] However, those with lower education, in general, are less likely to participate in stimulating cognitive activities than those who are more educated.[13] We were interested in whether those with lower education levels, who do engage in frequent cognitive activity, would show cognitive advantages similar to those with higher education. Because increased cognitive activity has shown notable effects on memory and executive functioning,[18,24–27] we expected to find a significant relationship for both cognitive measures.

Research has found a differential activation of brain regions as a function of type of cognitive activities.[28] For example, with reading tasks, the brain regions associated with memory and visual abilities are activated, while for activities involving searching the Internet, regions associated with reasoning are activated. In this study, the cognitive activities examined (i.e., reading, writing, listening to lectures, and doing word games) involve especially semantic memory processes. Thus, we expected that the compensatory effects of lower education would be stronger for memory than for executive functioning.

We predicted that those with lower education would engage in cognitive activities less frequently and would show poorer cognitive performance on episodic memory and executive functioning. We also expected that the negative effects of low education would be reduced for those engaging in frequent cognitive activities, especially memory performance. We expected these results to hold when controlling for age, sex, income, self-rated health, and frequency of moderate or vigorous physical activity. This would suggest that the effects would be consistent for men and women throughout adulthood and into old age, across income levels, would not be determined by poor self-rated health, and would contribute beyond the well-known benefits of physical exercise.[29–32]

METHODS

Study Sample

The participants were from the second wave of the Midlife in the United States study conducted in 2004–2006 with a national sample of noninstitutionalized adults selected by random digit dialing.[33] The sample of 3,640 consisted of those who had completed all measures used in this study. We excluded 297 participants who had reported a stroke, Parkinson disease, or other neurologic disorder, which could affect their cognitive performance. The resulting sample size analyzed was 3,343, with the age range from 32 to 84 years (M = 55.99, standard deviation [SD] = 12.21). Women comprised 55.4% of sample, and there were 39.4% participants with a 4-year college degree or higher.

Independent and Dependent Variables

The cognitive measures were obtained over the telephone, and all other measures were collected with a mail questionnaire.

Frequency of Engaging in Cognitive Activities. The cognitive activity variable was created by averaging the self-reported frequencies on a 6-point scale (1 = never, 2 = once a month, 3 = several times a month, 4 = once a week, 5 = several times a week, and 6 = daily) of engaging in four cognitive activities: reading books, magazines or newspapers; doing word games such as crossword, puzzles, or scrabble; attending educational lectures or courses; and writing (e.g., letters, journal entries, or stories).

Education. The level of education was operationalized as the total number of years of formal schooling.

Cognitive Performance. We assessed two factors: episodic memory and executive functioning. Seven cognitive dimensions, critical to adult functioning, were tested using the Brief Test of Adult Cognition by Telephone.[34,35] This included two measures of episodic verbal memory (immediate and delayed free recall of 15 words), working memory span (backward digit span—the highest span achieved in repeating strings of digits in reverse order), verbal fluency (the number of words produced from the category of animals in 60 seconds), inductive reasoning (completing the pattern in a series of five numbers), processing speed (the number of digits produced by counting backward from 100 in 30 seconds), and attention switching and inhibitory control (the Stop and Go Switch Task[35]). For the latter task, reaction times were calculated with the mean of switch and nonswitch trial latencies on a task requiring alternating between the "normal" condition (i.e., respond "Go" to the stimulus "Green" and "Stop" to the stimulus "Red") and the "reverse" condition (i.e., respond "Stop" to the stimulus "Green" and "Go" to the stimulus "Red"). Latencies were multiplied by (-1), so higher scores would correspond to faster reaction times.

An exploratory principal axis factor analysis with oblique rotation yielded two factors with eigenvalues greater than 1. Factor scores were computed by averaging the variables loading 0.30 and above on each factor and standardizing to *z* scores. The factors represent episodic memory (immediate and delayed word recall) and executive functioning (all other measures). The factors were correlated, $r(3{,}341) = 0.42$, $p < 0.001$, and accounted for 49% of the total variance. We also conducted confirmatory factor analysis with the seven cognitive tests and compared the fit of a one-factor model with the predicted two factor model. The two factor solution provided a good fit ($\chi^2_{[13]} = 266.675$, $p < 0.001$; root mean square error of approximation = 0.08; comparative fit index = 0.96; goodness of fit index [GFI] = 0.98; adjusted GFI = 0.95), which was superior to the one-factor results ($\chi^2_{[14]} = 1{,}939.217$, $p < 0.001$, root mean square error of approximation = 0.21, comparative fit index = 0.70, GFI = 0.81, adjusted GFI = 0.62).

Covariates

Demographic Variables. We examined age, sex (-1 = men, 1 = women), and total household income in dollars.

Self-Rated Health. Participants rated their physical health on a 5-point scale: In general, would you say your physical health is 1 = poor, 2 = fair, 3 = good, 4 = very good, or 5 = excellent?

Physical Activity. Twelve questions assessing the participant's frequency of vigorous (e.g., competitive sports such as running, vigorous swimming, high intensity aerobics; digging in the garden, or lifting heavy objects) and moderate intensity (e.g., leisurely sports such as light tennis, slow or light swimming, low-impact aerobics, or golfing without a power cart, brisk walking, and mowing the lawn with a walking lawnmower) of physical activity were used. These questions referred to frequency of physical activities separately for the summer and winter months, in three different settings (i.e., home, work, and leisure), with ratings from 1 = never, 2 = less than once a month, 3 = once a month, 4 = several times a month, 5 = once a week, and 6 = several times a week. We computed the mean across summer and winter in all three settings for both moderate and vigorous intensity. We selected the activity intensity and setting with the maximum value to represent the highest frequency of physical activity across all intensity levels and domains.

General Statistical Analysis

We computed the correlation coefficients among all covariates, independent, and dependent variables. To test our hypothesis, we conducted multiple regression analyses separately for the two cognitive factors. The effects of education, cognitive activity, and their interaction were tested while controlling for age, sex, self-rated health, household income, and frequency of physical activity.

RESULTS

Table 1 reports means, SDs, and intercorrelations of all variables. The results revealed, as expected, that those with higher education engaged more frequently in cognitive activities. Moreover, higher education and more frequent cognitive activity were associated with better episodic memory and executive functioning. We also examined the four separate cognitive activities from the composite and their bivariate relationships with the two cognitive factors. All these correlations were statistically significant and positive, ranging from 0.09 to 0.15. In the multiple regression models the covariates, age, sex, physical activity, and self-rated health, were significantly related to both cognitive measures, with income re-

TABLE 1. Means, Standard Deviations, and Intercorrelations Between All Covariates and Independent and Dependent Variables

	M	SD	Age	Sex	Education	Cognitive Activity Frequency	Physical Activity Frequency	Self-Rated Health	Income	Episodic Memory
Age (years)	55.99	12.21								
Sex (−1 = men, 1 = women)	—	—	−0.01							
Education (years)	14.31	2.71	−0.14[a]	−0.11[a]						
Cognitive activity frequency[b]	3.02	0.88	0.12[a]	0.15[a]	0.27[a]					
Physical activity frequency[b]	4.59	1.62	−0.27[a]	−0.10[a]	0.20[a]	0.10[a]				
Self-rated health[c]	3.64	0.97	−0.14[a]	−0.01	0.25[a]	0.12[a]	0.18[a]			
Income (dollars)	78,897.58	54,488.26	−0.26[a]	−0.09[a]	0.33[a]	0.05[a]	0.15[a]	0.21[a]		
Episodic memory (*z* scores)	0	1	−0.33[a]	0.23[a]	0.20[a]	0.18[a]	0.15[a]	0.17[a]	0.13[a]	
Executive functioning (*z* scores)	0	1	−0.42[a]	−0.11[a]	0.41[a]	0.19[a]	0.26[a]	0.28[a]	0.27[a]	0.42[a]

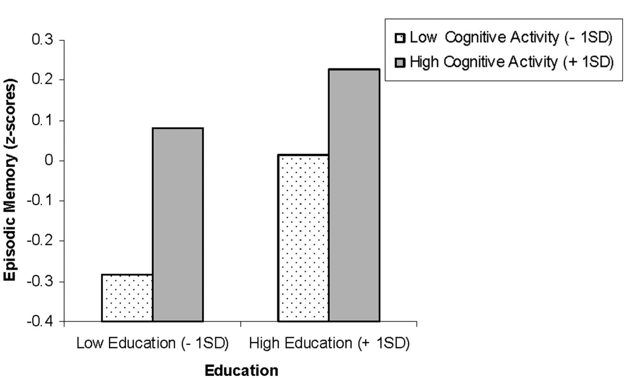
Notes: *M* = mean; SD = standard deviation.
[a]Correlation is significant at 0.01 level (two tailed), N = 3,343.
[b]Higher values on 1–6 scale indicate greater frequency.
[c]Higher values on 1–5 scale indicate higher self-rated health.

TABLE 2. Multiple Regressions With Episodic Memory and Executive Functioning as Dependent Variables

Predictors	*B*	*β*	*t*	p
Model 1 (DV = episodic memory)				
Education	0.041	0.111	6.370	<0.001
Cognitive activity	0.165	0.145	8.736	<0.001
Education × cognitive activity	−0.016	−0.037	−2.408	0.016
Model 2 (DV = executive functioning)				
Education	0.092	0.251	15.868	<0.001
Cognitive activity	0.184	0.161	10.711	<0.001
Education × cognitive activity	−0.007	−0.017	−1.237	.216

Notes: Model 1 with episodic memory as dependent variable: adjusted $R^2 = 0.216$, $F_{[8,\ 3{,}334]} = 115.919$, $p < 0.001$; Model 2 with executive functioning as dependent variable: adjusted $R^2 = 0.355$, $F_{[8,\ 3{,}334]} = 230.965$, $p < 0.001$; Models control for age, sex, physical activity, self-rated health, and income. *t* = *t*-test with *df* = 3,334. DV: dependent variable; *B*: unstandardized multiple regression coefficient; *β*: standardized multiple regression coefficient.

FIGURE 1. Predicted Values of Episodic Memory for Lower (−1 SD) and Higher (+1 SD) Cognitive Activity Frequency and Lower (−1 SD) and Higher (+1 SD) Levels of Education



Controlling for age, sex, physical activity, self-rated health, and income, there is an interaction between education and cognitive activity ($\beta = -0.037$, $t(3{,}334) = -2.408$, $p = 0.016$). SD = standard deviation, *t* = *t*-test.

lated only to executive functioning. Most importantly, as predicted, a significant interaction between education and cognitive activity was found for episodic memory, although not for executive functioning (Table 2). (We also tested quadratic effects of education and cognitive activity. For episodic memory, when the quadratics was included in the model, none of the higher order terms were significant. For executive functioning, the only significant higher order term was cognitive activity squared. These results showed that cognitive activity was positively related to executive functioning and the effects leveled off at the highest points.) This effect held after controlling for age, sex, household income, self-rated health, and physical activity frequency. Thus, for episodic memory, the disadvantages of lower education were attenuated by frequent cognitive activity across adulthood and old age (Fig. 1). For the figure, lower education (those without a 4-year college degree) and higher education (those with a 4-year college degree or more) correspond to 1 SD below and above the mean, respectively. The same approach was used to obtain the lower (−1 SD = several times a month or less) and higher (+1 SD = once a week or more) levels of engaging in cognitive activities.

CONCLUSIONS

We found that those with lower education had poorer cognitive performance for executive functioning and episodic memory and engaged in cognitive activities less frequently, which is consistent with previous research.[18] In addition, greater engagement in cognitive activities was associated with better memory and executive functioning.[18,24–27] Moreover, we found new evidence that the association between lower education and poorer memory can be moderated by engaging in frequent cognitive activities. These findings are promising for reducing the social disparities in cognitive aging, associated with educational attainment, using modifiable behavioral factors.[1]

There are some notable strengths of this study. It is based on a large national data set that includes a more diverse sample than many previous studies with regard to age and education levels. The study also includes a broad test battery that covers key aspects of cognition that are associated with cognitive aging and are sensitive to changes across the adult lifespan.[34,35] Notably, we found effects of cognitive activities after controlling for the effects of physical activity, whereas the unique variance of both types of activity has rarely been examined in other studies.

The finding that a modifiable behavior, cognitive activity, makes an even greater difference for the memory functioning of those with lower education levels than for those with higher education is an important contribution. This gives evidence of the possibility for some degree of personal control over cognitive functioning in adulthood by adopting a cognitively active life style, even for those who are at an educational disadvantage and who are at greatest risk for cognitive declines and dementia.[36] The results indicate that among those with lower education levels (i.e., 1 SD below the mean; those without a college education), engagement in more frequent cognitive activity, on the order of once a week or more (i.e., 1 SD above the mean), is associated with more than one third (0.36) of a SD increase in mean level of episodic memory.

If participating in accessible cognitive activities can compensate for a significant portion of the cognitive disadvantage of lower education in adulthood and old age, this can provide a useful prescription for improved functioning. It is impressive that those with lower education who engaged in frequent cognitive activities had memory performance more comparable with those with higher educational attainment (college degree or higher). The effects on episodic memory remained even when controlling for age, sex, income, and self-rated health, suggesting that the results hold across the adult age range of men and women and are not because of income or self-rated health differences. Moreover, the effects of cognitive activity were found over and above the effects of physical activity.[29–32] In contrast, for executive functioning, although cognitive activity was positively related, the effects did not vary by educational level.

The cognitive activities we examined may be a more robust compensatory factor for memory because they involve memory-related processes. Similar cognitive activities have been shown to alter responsiveness of the brain's neural circuits in middle-aged and older adults, with advantages for neuroplasticity in hippocampal functioning,[37,38] a region important for memory and learning.[39,40]

The study results are promising and suggest that the risks of lower education for poor cognitive performance, especially memory, may be attenuated with engagement in common cognitive activities such as writing, reading, attending lectures, or playing word games, at least once a week or more. The compensatory effects of cognitive activity for memory were most pronounced for those who have less education. For those with less education, these activities may afford enriched opportunities for using, rehearsing, and practicing memory-related skills required for reading, writing, processing verbal information, and playing games.

The study also has some limitations. As is typically found, the participants who completed all measures were positively selected compared with those not included in analyses due to incomplete data (i.e., included participants had higher education [14.28 versus 13.88 years] and better self-rated health [3.57

versus 3.45]). Also, the data are cross-sectional and cannot provide conclusive evidence about directionality. It is possible that those with lower education who have better cognitive performance are more likely to engage in cognitive activities. Moreover, we used a brief self-report measure of cognitive activity, and we do not know whether participants were accurate in their ratings. Thus, more research is needed to gain further insight into the processes whereby education, cognitive activity, and cognition are related in adulthood and old age. Additional work is also needed to determine whether engaging in frequent cognitive activities has a protective effect for dementia among those with lower education and for better-educated individuals.[22,23] Nevertheless, these findings hold promise for modifying risks of cognitive decline in less-advantaged populations, by encouraging frequent engagement in relatively accessible activities.

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