NIH Public Access
Author Manuscript
Psychol Aging. Author manuscript; available in PMC 2014 September 01.

Published in final edited form as:
Psychol Aging. 2013 September ; 28(3): 614–624. doi:10.1037/a0033103.

Cognitive decline impairs financial and health literacy among community-based older persons without dementia

Patricia A. Boyle, Ph.D.[1],[2], **Lei Yu, Ph.D.**[1],[3], **Robert S. Wilson, Ph.D.**[1],[3], **Eisuke Segawa, Ph.D.**[1], **Aron S. Buchman, M.D.**[1],[3], and **David A. Bennett, M.D.**[1],[3]

[1]Rush Alzheimer's Disease Center, Rush University Medical Center, Chicago, IL, USA

[2]Department of Behavioral Sciences, Rush University Medical Center, Chicago, IL, USA

[3]Department of Neurological Sciences, Rush University Medical Center, Chicago, IL, USA

Abstract

Literacy is an important determinant of health and well-being across the lifespan but is critical in aging, when many influential health and financial decisions are made. Prior studies suggest that older persons exhibit lower literacy than younger persons, particularly in the domains of financial and health literacy, but the reasons why remain unknown. The objectives of this study were to: a) examine pathways linking diverse resources (i.e., education, word knowledge, cognitive function, and decision making style) to health and financial literacy among older persons and determine the extent to which the relation of age with literacy represents a direct effect versus an indirect effect due to decrements in specific cognitive functions (i.e., executive functions and episodic memory), and b) test the hypothesis that declines in executive function and episodic memory are associated with lower literacy among older persons without dementia. 645 community-based older persons without dementia underwent detailed assessments of diverse resources, including education, word knowledge, cognitive function (i.e., executive function, episodic memory) and decision making style (i.e., risk aversion), and completed a measure of literacy that included items similar to those assessed in the Health and Retirement Study, such as numeracy, financial concepts such as compound inflation and knowledge of stocks and bonds, and important health concepts such as understanding of drug risk and Medicare Part D. Path analysis revealed a strong effect of age on literacy, with about half of the effect of age on literacy due to decrements in executive functions and episodic memory. In addition, executive function had an indirect effect on literacy via decision making style (i.e., risk aversion), and education and word knowledge had independent effects on literacy. Finally, among (n=447) persons with repeated cognitive assessments available for up to 14 years, regression analysis supported the association of multiple resources with literacy; moreover, more rapid declines in executive function and episodic memory over an average of 6.4 years prior to the literacy assessment predicted lower literacy scores (p's<0.02), but rate of decline in word knowledge did not. These findings suggest that diverse individual resources contribute to financial and health literacy and lower literacy in old age is partially due to declines in executive function and episodic memory.

Literacy is an important determinant of health and well-being across the lifespan, and lower literacy poses a major public health challenge in the United States. According to the United Nations Educational, Scientific, and Cultural Organization, literacy refers to the ability to identify, understand, interpret, and use written materials to function effectively in varying

---

Please address correspondence to: Patricia A. Boyle, Ph.D., Rush Alzheimer's Disease Center, Rush University Medical Center, 600 S. Paulina, 1020b, Chicago, IL 60612, Phone: 312-942-8749, Fax: 312-942-2297, Patricia_Boyle@Rush.edu.

None of the authors have any financial conflicts of interests to disclose in relation to this manuscript.

contexts (Kutner, Greenberg, Jin & Paulsen, 2003). Attainment of literacy involves a continuum of learning to acquire the knowledge needed to achieve goals, maximize potential, and function optimally in society. Low literacy affects about 90 million Americans and is a major problem among persons over the age of 65, the majority of which fall below basic competency levels (Dewalt, Berkman, Sheridan, Lohr & Pignone, 2004; Lusardi & Mitchell, 2007). Many older persons also perform poorly in two specific domains of literacy, health and financial literacy, which are critically necessary for the many complex and influential health and financial decisions older persons face (e.g., end of life healthcare choices, retirement planning, distribution of accumulated wealth) (Baker, Gazmararian, Sudeno & Patterson, 2000; Saha, 2006; Sudore et al., 2006; Wolf, Gazmarian & Baker, 2005; Wood et al., 2011). Among older persons, lower health literacy is associated with an increased risk of mortality and disability, higher health care expenditures, and less frequent use of preventive services (Baker et al., 2002; Baker et al., 2007; Baker, Wolf, Feinglass & Thompson, 2008; Peterson et al., 2011; Schillenger et al., 2002; Scott, Gazmarian, Williams & Baker, 2002; Sudore et al., 2006; Wolf, Gazmararian & Baker, 2005), and lower financial literacy is associated with poor savings and investment behaviors, limited wealth, and mental health complaints (Agarwal, Driscoll, Gabaix & Laibson, 2009; Bennett, Boyle, James & Bennett, 2012; Condelli, 2006; Lusardi & Mitchell, 2007a and b).

Despite increasing awareness that low levels of health and financial literacy threaten the health, economic security and well-being of literally millions of older Americans, to date, relatively little is known about the determinants of lower literacy in advanced age. Older persons may exhibit lower literacy due to longstanding influences such as limited education or word knowledge (Baker, 2006; Baker et al., 2007). However, aging often is accompanied by cognitive decline, and an emerging body of research suggests that cognitive function is related to literacy in old age, although a limitation of most studies is that they have not excluded persons with dementia who may be driving the association (Baker et al., 2008; Bennett et al. 2012; Wolf et al., 2012). Moreover, other individual resources (e.g., education, word knowledge, decision making style) contribute to literacy and are related to cognition, yet studies have not attempted to disentangle the effects of aging versus cognition on literacy in the context of related resources (Baker, 2006; Baker et al., 2008; Dewalt et al., 2004). An understanding of the complex interplay between aging, cognition and related resources that contribute to literacy is essential for the development of targeted interventions to improve literacy and consequently health and financial outcomes among the already large and rapidly growing population of older persons.

In this study, we present a conceptual model of how aging, cognition and other individual resources influence literacy and test several specific hypotheses about the pathways linking these resources to literacy (Figure 1). Our conceptual model was guided by existing literature and is based on the fundamental premise that attainment of health and financial literacy requires multiple inter-related skills that enable one to access, comprehend and process health and financial materials, understand and recall information, weigh alternatives, make inferences and decisions, communicate as needed in institutional settings, and engage in a life long process of learning (Baker, 2006, Baker et al., 2008, Institute on Medicine, 2004, Wolf et al., 2012). Thus, our model includes resources that are typically acquired early in life and well-established determinants of literacy such as education and word knowledge. Additionally, the model incorporates cognition, but we focus specifically on the domains of executive function and episodic memory since these abilities are widely known to be vulnerable to age-related decline and are fundamental to the acquisition of domain-specific literacy such as that studied here (Prull, Gabrielli & Bunge, 2000, Salthouse, 2000, Wolf et al., 2012). Finally, the model includes an indicator of decision making style (i.e., risk aversion). Although decision making style is rarely studied in the context of literacy, we included it because attainment of literacy requires interaction with the social environment and decision making under conditions of ambiguity (Baker, 2006), and risk aversion specifically can alter both the frequency and effectiveness of such interactions and decisions. Specifically, individuals who are highly risk averse may avoid exposure to new or uncertain educational or occupational experiences and tend to be less educated and prefer more secure but lower wages over less secure but potentially much higher wages; they also are less likely to become entrepreneurs (Bonin, Dohmen, Falk & Huffman, 2007; Cramer, Hartog, Jonker & Van Praag, 2002; Orazem & Mattilla, 1991). Thus, risk aversion may limit opportunities to gain new knowledge and experience as needed for the attainment of literacy, particularly domain-specific literacy, over the lifespan. Finally, risk aversion is related to cognitive function and the two may operate in tandem or interact to influence decision making and attainment of literacy in old age (Boyle, Yu, Buchman & Bennett, 2012; Boyle, Yu, Buchman, Laibson & Bennett, 2011; Mata, Josef, Samanez-Larkin & Hertwig, 2011). The approach used here extends prior work by directly examining the complex interplay between multiple individual resources that contribute to literacy, quantifying the effect of aging on literacy, and determining the extent to which the effect of aging is direct or indirect via cognition. Based on our conceptual model, we used path analysis to test the following specific hypotheses regarding the pathways linking age, cognition and other resources to literacy:

1. Aging has a direct effect on literacy, such that older age is associated with lower health and financial literacy.
2. The effect of age on literacy is partially due to an indirect effect of age on executive function and episodic memory.
3. The effect of executive function on literacy is partially due to an indirect effect of executive function on decision making style (i.e., risk aversion).
4. Additional resources (i.e., education and word knowledge) have independent effects on literacy.

Finally, because the hypotheses above were tested using cross sectional data and therefore preclude an understanding of whether cognitive decline is associated with reduced literacy, we next used longitudinal cognitive data collected for up to 14 years prior to the literacy assessment to test the hypothesis that declines in executive function and episodic memory are associated with decreased literacy among older persons without dementia.

Methods

Participants

Participants were from the Memory and Aging Project, an ongoing longitudinal study of common chronic conditions of old age (Bennett et al., 2005). Study participants are residents of approximately 40 senior housing facilities in the Chicago metropolitan area, including subsidized housing facilities, retirement communities, and retirement homes. Participation involves risk factor assessment, detailed annual clinical evaluations including medical history, neurological and neuropsychological examinations, and organ donation at the time of death. The study was approved by the Institutional Review Board of Rush University Medical Center, and informed consent was obtained from each participant following a detailed presentation of the risks and benefits associated with study participation.

The Memory and Aging Project began in 1997, and enrollment is ongoing. Literacy was assessed as part of a decision making assessment that began in 2010 (Boyle et al., 2012). At the time of these analyses, 1505 participants had completed the baseline evaluation for the parent study, including assessment of cognitive function; of those, 497 died and 102 refused further participation in the parent project before they were approached for a decision-making assessment. Of the remaining 906 potentially eligible persons, 670 completed the decision making assessment, 222 had not yet completed their decision-making baseline evaluation and 14 (1.5%) refused the decision-making assessment. Of the 670 participants who had completed the decision making assessment, 20 had dementia, and 5 had missing literacy data, leaving 645 persons eligible for these analyses. Among these persons, the assessments of cognitive function and literacy were completed at separate visits conducted a mean of 21 days apart (SD=43 days).

Clinical diagnoses

Based on a previously described structured clinical evaluation, all participants were classified by a clinician with respect to dementia and other conditions known to impair cognitive function in advanced age. The diagnosis of dementia followed the National Institute of Neurologic and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association criteria, which require a history of cognitive decline and evidence of impairment in at least two cognitive domains (McKhann, Drachman, Folstein, Katzman, Price & Stadler, 1984). Participants included in these analyses were free of dementia at the time of literacy assessment.

Assessment of literacy

Literacy was assessed via 32 questions designed to measure knowledge of financial and health information and concepts (Bennett, Boyle, James & Bennett, 2012; James, Boyle, Bennett & Bennett, 2012). There were 23 questions on financial literacy, many of which were adapted from the Health and Retirement Survey (Lusardi & Mitchell, 2007a and b). Questions assessed the ability to perform simple calculations (numeracy), and knowledge of financial concepts such as stocks, bonds and compound interest. There were 9 questions on health literacy, including questions on Medicare and Medicare Part D, following doctors' prescription instructions, leading causes of death in older persons, and understanding of drug risk. All answer choices were multiple choice or true/false, and each item was scored as correct or incorrect. Because of the difference in number of items across the domains of literacy, health and financial literacy scores were expressed as the percentage correct out of total items (from 0–100) within each domain and the total literacy score, the primary outcome, was the average of these two percentages. The test-retest reliability for the total literacy score over a 1 year interval was adequate (Intraclass Correlation Coefficient=0.75) (SACMOT, 2002). Further, using this measure of literacy, we have previously shown that literacy is related to engagement in health promoting behaviors, functional status, aspects of physical and mental health, and financial and healthcare decision making in this cohort of older persons (Bennett et al., 2012; James et al., 2012).

Assessment of executive function and episodic memory

In keeping with previous research (Alvarez & Emory, 2006; Barkley, 1997; Jurardo & Roselli, 2007), we define executive function as a higher order cognitive ability that encompasses four component processes: working memory (i.e., the ability to hold and manipulate information in short-term memory stores), attention (i.e., the ability to attend to relevant information and efficiently perform mental comparisons), verbal fluency (i.e., the ability to generate exemplars within a specific category), and inhibition (i.e., the ability to regulate strong or automatic responses and minimize susceptibility to interference). Working memory was assessed via three measures, Digit Span Forward and Backward (Weschler, 1987) and Digit Ordering (Cooper, Sagar, Jordan, Harvey, & Sullivan, 1991; Wilson et al., 2002), as done in prior work (Cherry et al., 2012; Gibbons et al., 2012; Hoppe, Muller, Werkheid, Thone & Von Cramon, 2000). Attention was assessed via two commonly used tests, an oral version of the Symbol Digit Modalities Test (Smith, 1982) and Number Comparison (Cherry et al., 2012; Dong et al., 2012; Ekstrom, French, Harman & Kermon, 1976; Gibbons et al., 2012). Verbal fluency was assessed via two measures of category fluency, animals and fruits and vegetables (Cherry et al., 2012; Gibbons et al., 2012; Wilson et al., 2002). Finally, inhibition was assessed via 2 indices from a modified version of the Stroop Neuropsychological Screening test (Lezak, 2004; Cherry et al., 2012). Raw scores on all 9 tests were converted to z-scores using the mean and standard deviation of the cohort at baseline and averaged to create a composite measure of executive function. We have used a similar approach to define executive function in a prior publication (Boyle, Yu, Buchman & Bennett, 2012).

Episodic memory, the ability to learn and retain new information, was assessed via 7 tests including immediate and delayed recall of story A from Logical Memory of the Weschler Memory Scale (Weschler, 1987), immediate and delayed recall of the East Boston Story (Albert et al., 1991), Word List Memory, Word List Recall, and Word List Recognition (Morris et al., 1989), as done in prior work (Albert et al., 1991; Dong et al., 2010; Fyffe et al., 2011; Wilson et al., 2002). Raw scores on all 7 tests were converted to z-scores using the mean and standard deviation of the cohort at baseline and averaged to create a composite measure of episodic memory (Wilson, Bienias, Berry-Kravis, Evans, & Bennett, 2002; Wilson et al., 2002).

Other resources and covariates

Age (based on date of birth and date of assessment), sex, education (years of schooling), and race were self-reported.

Word knowledge involves two inter-related abilities, reading and vocabulary (Hawkins et al., 1993), and was assessed via a 15-item version of the National Adult Reading Test (Nelson, 1982) and a 15-item version of the Boston Naming Test (Kaplan, Goodglass and Wientraub, 1983). Raw scores on both tests were converted to z-scores using the mean and standard deviation of the cohort at baseline and averaged to create a composite measure of word knowledge.

Risk aversion, an indicator of decision making style that reflects the tendency to prefer a safe option over an uncertain but potentially better option, was assessed via a series of 10 questions used in standard behavioral economics approaches; answers on all 10 items were used to create a coefficient of risk aversion, and higher scores indicate higher risk aversion (Boyle et al., 2012).

Income was measured using the show card methodology, as previously described (Bennett et al., 2005). Self-reported annual income was ranked according to 10 possible categories: 1: $0–$4999, 2: $5000–$9999, 3: $10000–$14999, 4: $15000–$19999, 5: $20000–$24999, 6: $25000–$29999, 7: $30000–$34999, 8: $35000–$49999, 9: $50000–$74999, 10: >$75000 (Bennett et al. 2005).

Data analysis

First, we used path analysis to test specific hypotheses regarding the causal pathways linking aging, cognition and other resources with literacy. Relationships among variables of interest were estimated using PROC CALIS procedure of SAS/STAT software, version 9.3 (SAS, 2009). Advantages of using path analysis include the generality and flexibility of model specification and the ability to assess fit of the hypothesized model to the observed data. In addition, compared to common analytic approaches such as multiple linear regression, path analysis allows for simultaneous estimation of direct and indirect effects of age on literacy. Overall model fit was examined comprehensively with 5 different fit indices. The chi-square test statistic and the standardized root mean square residuals (SRMSR) were used to assess

NIH-PA Author Manuscript

NIH-PA Author Manuscript

the absolute model fit. A significant p-value for the chi-square test indicates overall lack of fit, while a value of SRMSR under 0.05 indicates a reasonably good fit. To further take into consideration model parsimony, we assessed the model with root mean square error of approximation (RMSEA). RMSEA estimate penalizes models with a larger number of parameters, the closer to zero a value of RMSEA the better, and a model is preferred to have RMSEA estimate under 0.05 and an upper bound of the 90% RMSEA Confidence Intervals (CI) less than 0.06 (Hu & Bentler, 1999). Two additional incremental measures of fit, namely Comparative Fit Index (CFI) and Normed Fit Index (NFI), were used to compare the fitness of our proposed model with that of a baseline model assuming uncorrelatedness. A model is considered to have a good fit if values of these two indices are above 0.95. In this analysis, we accepted goodness of fit only if the model jointly satisfied all 5 fit indices, including a non-significant chi-square statistic, SRMSR<0.05, RMSEA<0.05, and both CFI and NFI >0.95. Upon establishing goodness of fit, standardized path loadings and the standardized total direct and indirect effects of aging and other resources on literacy were reported.

Next, to investigate the association between the prior rate of change in cognition and the level of literacy, we estimated the slopes of executive cognitive decline, episodic memory decline, and word knowledge decline for each individual by fitting a linear mixed model to all available longitudinal cognitive testing data prior to the time of literacy assessment, adjusted for baseline age, sex, and years of education. These person-specific slopes were then used in ordinary least squares regressions as the predictors of literacy; the model was adjusted for age at the time of literacy assessment, sex, education, starting levels of executive function, episodic memory, and word knowledge, and risk aversion at the time of literacy assessment. This analysis was done in SAS and models were validated graphically and analytically (SAS, 2009).

Results

Descriptive data are provided in Table 1. Participants correctly answered a mean of 67.4% (SD=14.6) of the literacy questions, with higher scores indicating better literacy. The intercorrelations among key resource variables are shown in Table 2. Bivariate correlation analyses revealed that the literacy total score was negatively associated with age (r=−0.32, p<.001) and risk aversion (r=−0.23, p<0.001) and positively associated with education (r= 0.39, p<.001), executive function (r= 0.54, p<.001), episodic memory (r= 0.43 p<.001), and word knowledge (r=0.46, p<0.001). Males on average had higher literacy scores compared to women (t(643)=−4.77, p=<0.001).

Pathways linking age, cognition and other resources with literacy

First, we used path analysis to examine the influence of age and other resources on literacy and determine the extent to which the relation of age with literacy was due to direct or indirect effects of aging on executive functions and episodic memory. In keeping with our hypotheses, the model (Figure 2) included paths that linked age to literacy directly, as well as paths that linked age to episodic memory and executive functions, which in turn each linked to literacy. In addition, we included separate paths linking other hypothesized resources to literacy (i.e., education, word knowledge, decision making style), and we assume no direct paths between age and these resources. Finally, based on prior literature showing an association of cognition, particularly executive function, with risk aversion, the model included paths from executive function to risk aversion and risk aversion to literacy (Boyle et al., 2012). This model provided a very good overall fit to the data (Pr>Chi-Square= 0.180, SRMSR=0.030, RMSEA=0.028 (90% CI: 0–0.067), CFI=0.997, and NFI=0.993) and all parameter estimates for individual paths in the proposed model were significant as hypothesized. The total standardized effect of age on literacy was −0.28

NIH-PA Author Manuscript

NIH-PA Author Manuscript

(SE=0.032, p<0.001). When partitioned, approximately half of the total effect was attributable to a direct effect of age on literacy (Est=−0.151, SE=0.032, p<0.001), and approximately half to an indirect effect of age on literacy through executive functions and episodic memory (Est=−0.129, SE=0.017, p<0.001). Episodic memory was directly related to literacy (Est=0.180, SE=0.035, p<0.001). The total effect of executive function on literacy was 0.29 (Est=0.286, SE=0.038, p<0.001), most of which was attributable to a direct effect (Est=0.264, SE=0.038, p<0.001) but a proportion was due to an indirect effect through decision making style (i.e., risk aversion; Est=0.023, SE=0.007, p=0.002). Separately, education and word knowledge were directly related to literacy (Est=0.184, SE=0.032, p<0.001 and Est=0.168, SE=0.035, p<0.001, respectively), suggesting they had independent effects.

To examine the robustness of our conceptual model, we used path analysis to test slightly modified versions in which we added or deleted various plausible paths for comparison with the original model. For example, because episodic memory may also directly influence risk aversion, we added a path from episodic memory to risk aversion. We also added a path from age to risk aversion, because the association of age with risk aversion remains unclear (Boyle et al., 2012). None of these modifications improved the fit of the model. Thus, we conclude that our hypothesized model best fit the observed data.

Lower literacy as a function of cognitive decline

The findings from the path analysis support our hypothesis that multiple individual resources contribute to literacy in old age and suggest that a considerable proportion of the effect of age on literacy is due to age-related decrements in executive functions and episodic memory. However, the path analysis was based on cross-sectional data and therefore does not inform on the extent to which cognitive decline is associated with lower literacy in advanced age. Thus, to address this question, we examined the relation of the prior rate of change in executive function and episodic memory with the level of literacy; in addition, because changes in word knowledge may also contribute to literacy, we included a term for the prior rate of change in word knowledge. These analyses were based on 447 persons without dementia with at least 2 prior cognitive evaluations. These persons had annual cognitive data for a mean of 6.4 years (SD=2.7, range: 2–14). We used the composite measures of executive function, episodic memory and word knowledge and constructed mixed-effects models with a term for time (since baseline in years) to estimate each person’s annual rate of cognitive change within each domain (i.e., slope). Executive function declined at a mean of 0.038 unit per year (SD=0.032, range: −0.176-0.057), episodic memory at a mean of 0.003 per year (SD=0.048, range: −0.220-0.129), and word knowledge at a mean of 0.003 per year (SD=0.011, range: −0.058-0.042).

Next, to test the hypothesis that the rate of change in executive and memory function over up to 14 years prior to the assessment of literacy predicted the level of literacy, we used the slopes of cognitive decline (as estimated above) and constructed a linear regression model with the literacy total score as the outcome and terms for the executive slope, episodic memory slope, word knowledge slope, the starting levels of executive function, episodic memory, and word knowledge, age at the time of literacy assessment, sex, education, and risk aversion at the time of literacy assessment. The results of this analysis were consistent with the findings from the path analysis in that diverse resources were relatively independently associated with literacy (Table 3); further, consistent with our hypothesis, this analysis showed that a more rapid rate of decline in executive function and episodic memory were associated with lower literacy, but the rate of decline in word knowledge was not. To clarify the magnitude of these effects, we can multiply the estimate for executive slope (0.546) by the standard deviation of executive function (0.032) and divide the product by the estimate for education (0.009); this calculation [(0.546 × 0.032)/0.009] shows that, when the rate of decline in executive function increased by one standard deviation, the reduction in the literacy total score was equivalent to having 1.94 fewer years of education. Similarly, when the rate of decline in episodic memory increased by 1 standard deviation (0.048), the average reduction in the total literacy score was equivalent to the effect of having 4.03 fewer years of education [(0.755 × 0.048)/0.009].

In subsequent analyses, to examine the potential role of race and income on the association of literacy with cognitive decline, we repeated the model just described with additional terms for race and income; the terms for race (estimate=0.0727, SE=0.0201, $p<0.001$) and income (estimate=0.0063, SE=0.0027, $p=0.022$) were significant, but declines in executive function and memory remained associated with decreased literacy (p's<0.005).

Discussion

In a cohort of 645 well-characterized community-based older persons without dementia, we used path analysis to test several hypothesized pathways linking age, cognition and other individual resources with literacy in advanced age. Results showed that literacy is a function of diverse individual resources in old age. Age was strongly related to literacy, but about half of the association of age with literacy was due to an indirect effect of age on executive function and episodic memory. Executive function also had an indirect effect via risk aversion, and word knowledge ability and education had independent effects on literacy. Further, in an analysis using longitudinal cognitive data for up to 14 years from a subset of 447 persons, rates of decline in executive function and memory were associated with a lower level of literacy, but rate of decline in word knowledge was not; this analysis adjusted for age, sex, education, and starting level of cognition in each domain, starting level of word knowledge, and risk aversion. The associations of executive function and episodic memory decline with literacy persisted after adjustment for race and income. These findings suggest that multiple resources contribute to literacy and that aging and cognitive decline, particularly decline in executive function and episodic memory, degrade the domain-specific literacy (i.e., financial and health literacy) most needed to maintain wealth, health and well-being in late life.

Prior studies have established cross sectional associations of cognition and other resources with literacy among older persons (Baker et al., 2008; Bennett et al., 2012; Wolf et al., 2012); however, the existing studies have not examined the inter-relationships among diverse resources, making it difficult to fully elucidate the role of individual resources as determinants of literacy in late life (Baker, 2006; Dewalt et al., 2004). This study provides evidence that multiple resources, some of which reflect primarily early life conditions (i.e., education, word knowledge) and others that reflect late life challenges (e.g., cognitive decline), influence literacy in old age. Notably, about half of the association of age with literacy was due to decrements in executive functions and memory. That is not surprising, given that aging preferentially affects these domains of cognition and prior work has shown that the impact of health literacy on health outcomes is partially mediated by cognitive abilities (Prull, Gabrielli & Bunge, 2000; Salthouse, 2000; Wolf et al., 2012). What is surprising, however, is that age also had a separate direct effect on literacy. This suggests that age is somehow affecting other (as yet unknown) skills or behaviors to influence literacy. Further, the finding that executive function works in part through risk aversion to affect literacy suggests that additional focus on the relation between cognition and decision making style (considered more broadly) may help elucidate the factors that degrade literacy in old age.

The finding of a relation between rates of decline in executive function and episodic memory and literacy among older persons without dementia has major public health implications. There are currently about 40 million persons over the age of 65 in the US and by 2030, there will be more than 70 million. Older persons are confronted with a host of challenging healthcare and financial decisions (e.g., Medicare part D plan selection, assisted living/nursing home transitions, investment of retirement savings, social security distributions) that require domain-specific literacy such as that measured here. Unlike younger persons, older persons do not have the luxury of time and future opportunity to overcome decisional errors. Prior research has established that literacy is associated with numerous financial and health outcomes and well-being, indicating that lower literacy compromises the ability of older persons to make the many difficult financial and health decisions they face (Baker et al., 1997; Howard, Sertell & Gazmarian, 2006; Dewalt et al., 2011; Howard, Gazmarian & Parker, 2005; Institute of Medicine, 2004; Lindquist et al., 2011). Although it is intuitive to assume that literacy remains unchanged among older persons without dementia, our findings suggest that the relatively subtle cognitive decline that occurs even among persons without dementia can detrimentally impact literacy. Thus, lower literacy may partially reflect an early manifestation of age-related cognitive decline and may serve as an indicator of future adverse outcomes.

It is noteworthy that, in this study of non-demented persons, participants answered only about 67% of the literacy questions correctly. This finding is somewhat alarming, given that we have previously shown that performance on this measure of literacy is related to a wide variety of positive aspects of health, including more frequent participation in health promoting behaviors including cognitive, physical and social activities, less functional disability, and better mental health (Bennett et al., 2012). We also have shown that literacy is positively associated with financial and health decision making even after controlling for the level of cognitive function (James et al., 2012), and the beneficial effect of literacy on decision making was stronger among older persons, poorer persons and persons at the lower ranges of cognitive ability. Taken together, these data suggest that higher literacy in old age is associated with better health and better decision making, even after adjustment for the level of cognition; thus, while related, literacy and cognition are tapping into somewhat different constructs. Ultimately, with effective intervention, improvements in literacy could facilitate better decision making and lead to better health and quality of life in later years.

The finding that impaired literacy in old age is in part a function of cognitive decline even among non-demented persons has clear implications for public policy and interventions to improve literacy in old age. In particular, these data suggest that financial and health-related materials should be redesigned to make them are more accessible, understandable, and relevant, particularly for persons with even a mild degree of cognitive compromise. Thus, a chief priority is to reduce the cognitive demands, particularly higher order complex reasoning abilities and memory, inherent in the health and financial materials and decision making aids used by older persons. For example, Programs such as Medicare part D likely involve too much complexity for optimal use by older persons (Wood et al., 2011). The need to reduce cognitive demands is supported by studies of applied decision making that have shown that information presentation and framing strongly influence what data are attended to and used in decisions such as making hospital choices (Hibbard & Peters, 2003; Peters, Dieckmann, Dixon, Hibbard & Mertz, 2007). These studies suggest that specific strategies such as limiting the information presented and highlighting the meaning of important information can aid in decision making, particularly among persons with low numeracy, a component of literacy as measured here (Peters et al., 007). Further, in light of our finding that executive functions were related to literacy, other strategies may include reducing the number of options or layering information using clear, straight forward language (not jargon) that minimizes the need for working memory and set shifting and highlights salient differences between options. In addition, since episodic memory also is related to literacy, reducing memory demands by using external aids (e.g., keeping essential plan information visible at all times for review, use of pill boxes, and doctor's visit and bill payment reminders) may enhance recall and prompt better financial and heath literacy and behaviors.

Finally, our data suggest that cognition also may work through decision making styles such as risk aversion to influence literacy. Prior research suggests that persons with lower cognition who are highly risk averse may limit exposure to important learning experiences and have poorer educational and occupational outcomes (Orazem & Mattilla, 1991; Cramer et al., 2002). In addition, in old age, risk averse persons exhibit poorer financial and health decision making (Boyle et al., 2012). Efforts to encourage older persons to actively engage in decision making and weigh alternatives carefully rather than choosing the "safe" option might improve literacy and related outcomes (Institute on Medicine, 2004). In keeping with this idea, studies of applied decision making have shown that patient activation (the willingness to participate actively in managing one's health) is associated with better health behaviors and decisions (Hibbard, Peters, Dixon & Tusler, 2007). It is possible that efforts to increase activation more broadly may help risk averse persons in particular to overcome the tendency to avoid new or intimidating situations and decisions. Moreover, activation strategies may increase older persons' motivation to access and utilize information as required for attainment of health and financial literacy in old age.

The neurobiologic basis of the association of cognition with literacy is unknown. However, it is now widely recognized that Alzheimer's disease pathology is commonly present in the brain and associated with subtle cognitive decrements even among persons without dementia (Aizenstein et al., 2008; Bennett et al., 2006). Further, we have shown that Alzheimer's disease and other common age-related neuropathologies are associated with the rate cognitive decline even before the onset of dementia (Wilson et al., 2010). Thus, we suspect that accumulating Alzheimer's disease pathology may underlie the association of cognitive decline and literacy among non-demented older persons and we hypothesize that decreased literacy in non-demented older persons is due to subclinical disease. Future clinical-pathologic studies are needed to confirm that pathology degrades literacy in persons without dementia, as such findings would have direct and compelling implications for how we think about the effects of aging prior to the onset of dementia. Specifically, they would suggest that there is an element of disease-related aging that affects a host of behaviors even before frank dementia becomes evident. This is consistent with prior work showing that impairments in decision making are present prior to the onset of and a risk factor for conversion to dementia (Sherod et al., 2009; Triebel et al., 2009). Perhaps even more alarming, however, are findings showing that a sizable proportion of older persons, even those without overt cognitive problems (no dementia or even mild cognitive impairment), are susceptible to deceptive advertising and show poor decision making and an increased vulnerability to scams (Boyle et al., 2012; Denburg et al., 2007). Increased focus on and awareness of these very early manifestations of cognitive decline may facilitate earlier identification of persons at risk for developing dementia and other adverse outcomes.

This study has strengths and limitations. One novel feature of this study was that it utilized a measure of literacy that focused on the domain-specific health and financial skills older persons need to make good decisions and function optimally in society. Another strength is the focus on non-demented, community-based persons. Participants were evaluated at regular intervals for an average of 6.4 years with a very high rate of follow-up participation and cognition was assessed with previously established, psychometrically sound measures. These factors enhanced our ability to characterize person-specific changes in cognition and to examine the relation between cognitive decline and literacy. Limitations are that literacy was assessed only at a single point in time, making it difficult to establish the temporal relation between cognition and literacy, and that participants were selected. In addition, although we measured four components of executive function using tests that have been used in prior studies, it may be the case that some of the effects of age that did not work though executive function as measured here could be captured by additional measures of executive functioning that assess planning, set shifting or cognitive flexibility. Finally, a limitation of literacy research in general is that lower literacy is known to be associated with low wealth, poor health, and other adverse outcomes but, as with the present findings on cognitive decline, it is difficult to establish the direction of causation. To date, little is known about the sources, nature, and importance of mistaken financial and health decisions in old age. Considerable measurement challenges underlie this lack of knowledge, in particular the difficulty of collecting data on wealth, financial literacy and spending, and this study is limited by similar challenges and holes in data. Future research on literacy and decision making is greatly needed to better understand the how these factors influence health and well-being in advanced age, as this line of research has the potential to reduce the considerable economic and public health challenge posed by lower literacy and poor decision making. Ultimately, such data will inform interventions to improve literacy and promote independence, wealth, health, and well-being among older persons.

Acknowledgments

We thank the many Illinois residents for participating in the Rush Memory and Aging project; Traci Colvin, MPH, and Tracey Nowakowski for managing the study; Woojeong Bang, MS for statistical programming and analysis; and John Gibbons, MS, and Greg Klein, MS, for data management. We are indebted to the participants and the staff of the Rush Memory and Aging Project and the Rush Alzheimer's Disease Center for this work. The study was supported by NIA grants R01AG17917 (Bennett), R21AG30765 (Bennett), R01AG34374 (Boyle) and R01AG33678 (Boyle).

References

Albert M, Smith L, Scherr P, Taylor J, Evans D, Funkenstein H. Use of brief cognitive tests to identify individuals in the community with clinically diagnosed Alzheimer's disease. International Journal of Neuroscience. 1991; 57:167–178. [PubMed: 1938160]

Agarwal S, Driscoll JC, Gabaix X, Laibson D. The age of reason: financial decisions over the life-cycle and implications for regulation. Brookings Papers on Economic Activity. 2009; 2:51–117.

Aizenstein HJ, Nebes RD, Saxton JA, Price JC, Mathis CA, Tsopelas ND, Ziolko SK, James JA, Snitz BE, Houck PR, Bi W, Cohen AD, Lopresti BJ, DeKosky ST, Halligan EM, Klunk WE. Frequent amyloid deposition without significant cognitive impairment among the elderly. Archives of Neurology. 2008; 65(11):1509–1517. [PubMed: 19001171]

Alvarez JA, Emory E. Executive function and the frontal lobes: a meta-analytic review. Neuropsychology Review. 2006; 16(1):17–42. [PubMed: 16794878]

Baker DW. The meaning and the measure of health literacy. Journal of General Internal Medicine. 2006; (8):878–883. [PubMed: 16881951]

Baker DW, Gazmararian JA, Sudano J, Patterson M. The association between age and health literacy among elderly persons. Journal of Gerontology B Psychological Sciences. 2000; 55(6):S368–374.

Baker DW, Parker RM, Williams MV, Clark WS, Nurss J. The relationship of patient word knowledge ability to self reported health and use of health services. American Journal of Public Health. 1997; 87:1027–1030. [PubMed: 9224190]

Baker DW, Gazmararian JA, Williams MV, Scott T, Parker RM, Green D, Ren J, Peel J. Functional health literacy and the risk of hospital admission among Medicare managed care enrollees. American Journal of Public Health. 2002; 8:1278–1283. [PubMed: 12144984]

Baker DW, Wolf MS, Feinglass J, Thompson JA, Gazmararian JA, Huang J. Health literacy and mortality among elderly persons. Archives of Internal Medicine. 2007; 167:1503–1509. [PubMed: 17646604]

Baker DW, Wolf MS, Feinglass J, Thompson JA. Health literacy, cognitive abilities, and mortality among elderly persons. Journal of General Internal Medicine. 2008; 6:723–726. [PubMed: 18330654]

Barkley R. Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory. Psychological Bulletin. 1997; 121:65–94. [PubMed: 9000892]

Bennett DA, Schneider JA, Arvanitakis Z, Kelly JF, Aggarwal NT, Shah RC, Wilson RS. Neuropathology of older persons without cognitive impairment from two community-based studies. Neurology. 2006; 27(66):1837–1844. [PubMed: 16801647]

Bennett DA, Schneider JA, Buchman AS, Mendes de Leon C, Bienias JL, Wilson RS. The Rush Memory and Aging Project: study design and baseline characteristics of the study cohort. Neuroepidemiology. 2005; 25:163–175. [PubMed: 16103727]

Bennett J, Boyle PA, James BD, Bennett DA. Correlates of Health and financial literacy in older adults without dementia. BMC Geriatrics. 2012; 12(1):30. [PubMed: 22691341]

Bonin H, Dohmen T, Falk A, Huffman D, Sunde W. Cross-sectional earnings risk and occupational sorting: The role of risk attitudes. Labour Economics. 2007; 14:926–937.

Boyle PA, Yu L, Buchman AS, Bennett DA. Risk aversion is associated with decision making among community-based older persons. Frontiers in Psychology. 2012; 3:205. [PubMed: 22754545]

Boyle PA, Yu L, Buchman AS, Laibson DI, Bennett DA. Cognitive function is associated with risk aversion in community-based older persons. BMC Geriatrics. 2011; 11:53. [PubMed: 21906402]

Boyle PA, Yu L, Wilson RS, Aggarwal NT, Tang Y, Bennett DA. Mild cognitive impairment: risk of Alzheimer disease and rate of cognitive decline. Neurology. 2006; 67(3):441–445. [PubMed: 16894105]

Boyle PA, Yu L, Wilson RS, Gamble K, Buchman AS, Bennett DA. Poor decision making is a consequence of cognitive decline among older persons without Alzheimer's disease or mild cognitive impairment. PLoS One. 2012; 7(8):e43647. [PubMed: 22916287]

Cherry BJ, Zettel-Watson L, Shimizu R, Roberson I, Rutledge DN, Jones CJ. Cognitive performance in women aged 50 years and older with and without fibromyalgia. The Journals of Gerontology Series B: Psychological Sciences and Social Science. 2012 Dec 28.:12. [Epub ahead of print].

Condelli, L. The American Institutes for Research. Washington, DC: 2006. A review of the literature in adult numeracy: Research and conceptual issues.

Cooper JA, Sagar HJ, Jordan N, Harvey NS, Sullivan EV. Cognitive impairment in early, untreated Parkinson's disease and its relationship to motor disability. Brain. 1991; 114:2095–2122. [PubMed: 1933236]

Cramer JS, Hartog J, Jonker N, Van Praag CM. Low risk aversion encourages the choice for entrepreneurship: an empirical test of a truism. Journal of Economic Behavior and Organization. 2002; 48:29–36.

Denburg NL, Cole CA, Hernandez M, Yamada TH, Tranel D, Bechara A, Wallace RB. The orbitofrontal cortex, real-world decision making, and normal aging. Annals of the New York Academy of Sciences. 2007; 21:480–498. [PubMed: 17872394]

Dewalt DA, Berkman ND, Sheridan S, Lohr KN, Pignone MP. Literacy and health outcomes: a systematic review of the literature. Journal of General Internal Medicine. 2011; 19:1228–1239. [PubMed: 15610334]

Dong X, Simon MA, Wilson RS, Mendes de Leon CF, Rajan KB, Evans DA. Decline in cognitive function and risk of elder self-neglect: finding from the Chicago Health Aging Project. Journal of the American Geriatrics Society. 2010; 58(12):2292–2299. [PubMed: 21143438]

Ekstrom, RB.; French, JW.; Harman, HH.; Kermen, D. Manual for kit of factor-referenced cognitive tests. Princeton, NJ: Educational Testing Service; 1976.

Fyffe DC, Mukherjee S, Barnes LL, Manly JJ, Bennett DA, Crane PK. Explaining differences in episodic memory performance among older African Americans and Whites: the roles of factors related to cognitive reserve and test bias. Journal of the International Neuropsychological Society. 2011; 17(4):625–638. [PubMed: 23131601]

Gibbons LE, Carle AC, Mackin RS, Harvey D, Mukherjee S, Insel P, Curtis SM, Mungas D, Crane PK. A composite score for executive functioning, validated in Alzheimer's Disease Neuroimaging Initiative (ADNI) participants with baseline mild cognitive impairment. Brain Imaging and Behavior. 2012; 6:517–527. [PubMed: 22644789]

Hawkins KA, Sledge WH, Orleans JF, Quinlan DM, Rakfeldt J, Huffman RE. Normative implications of the relationship between reading vocabulary and Boston naming test performance. Archives of Clinical Neuropsychology. 1993; 8(6):525–537. [PubMed: 14591992]

Hibbard JH, Peters E. Supporting Informed Consumer Health Care Decisions: Data Presentation Approaches that Facilitate the Use of Information in Choice. Annual Review of Public Health. 2003; 24:413–433.

Hibbard JH, Peters E, Dixon A, Tusler M. Consumer competencies and the use of comparative quality information: it isn't just about literacy. Medical Care Research Review. 2007; 64(4):379–394. [PubMed: 17684108]

Hoppe CD, Müller UD, Werheid KD, Thöne AD, von Cramon YD. Digit ordering test: clinical, psychometric, and experimental evaluation of a verbal working memory test. Clinical Neuropsychology. 2000; 14:38–55.

Howard DH, Gazmararian J, Parker RM. The impact of low health literacy on the medical costs of Medicare managed care enrollees. American Journal of Medicine. 2005; 118:371–377. [PubMed: 15808134]

Howard DH, Sentell T, Gazmararian JA. Impact of health literacy on socioeconomic and racial differences in health in an elderly population. Journal of General Internal Medicine. 2006; 21:857–861. [PubMed: 16881947]

Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling. 1999; 6(1):1–55.

Institute of Medicine. Health Literacy: A Prescription to End Confusion. National Academies Press; Washington, DC: 2004.

James BD, Boyle PA, Bennett JS, Bennett DA. The impact of health and financial literacy on decision making in community-based older adults. Gerontology. 2012; 58(6):531–539. [PubMed: 22739454]

Jurado BM, Rosselli M. The elusive nature of executive functions: a review of our current understanding. Neuropsychology Review. 2007; 17:213–233. [PubMed: 17786559]

Kaplan, EF.; Goodglass, H.; Weintraub, S. The Boston Naming Test. Philadelphia: Lea & Febiger; 1983.

Kutner, M.; Greenberg, E.; Jin, Y.; Paulsen, C. The Health Literacy of America's Adults: Results From the 2003 National Assessment of Adult Literacy (NCES 483). National Center for Education Statistics. U.S. Department of Education; Washington, DC: 2006.

Lezak, MD.; Howieson, DB.; Loring, DW. Neuropsychological Assessment. 4. New York: Oxford University Press; 2004.

Lindquist LA, Go L, Fleisher J, Jain N, Friesema E, Baker DW. Relationship of Health Literacy to Intentional and Unintentional Non-Adherence of Hospital Discharge Medications. Journal of General Internal Medicine. 2011; 27:173–178. [PubMed: 21971600]

Lusardi A, Mitchell OS. Baby Boomer retirement security: The roles of planning, financial literacy, and housing wealth. Journal of Monetary Economics. 2007; 54:205–224.

Lusardi A, Mitchell OS. Financial literacy and retirement preparedness: evidence and implications for financial education. Business Economics. 2007; 42:35–44.

Mata R, Josef AK, Samanez-Larkin GR, Hertwig R. Age differences in risky choice: a meta-analysis. Annals of the New York Academy of Science. 2010; 1(235):18–29.

McKhann G, Drachman D, Folstein M, Katzman R, Price D, Stadlan EM. Clinical diagnosis of Alzheimer's disease: report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. Neurology. 1984; 34:939–944. [PubMed: 6610841]

Morris J, Heyman A, Mohs R, Hughes J, van Belle G, Fillenbaum G, et al. The consortium to establish a registry for Alzheimer's disease (CERAD): I. Clinical and neuropsychological assessment of Alzheimer's disease. Neurology. 1989; 39:1159–1165. [PubMed: 2771064]

Orazem PF, Mattila JP. Human capital, uncertain wage distributions and occupational and educational choices. International Economic Review. 1991; 32:103–122.

Prull, MW.; Gabrieli, JDE.; Bunge, SM. Age-related changes in memory: A cognitive neuroscience perspective. In: Craik, FIM.; Salthouse, TA., editors. Handbook of aging and cognition. Vol. 2. Erlbaum; Mahweh: 2000. p. 91-153.

Saha S. Improving literacy as a means to reducing health disparities. Journal of General Internal Medicine. 2006; 21:8936–8945.

Salthouse TA. Aging and measures of processing speed. Biological Psychiatry. 2000; 54:35–54.

SAS 9.2 Help and Documentation [computer program]. SAS Institute Inc; Cary, NC: 2009.

Schillinger D, Grumbach K, Piette J, Wang Osmond D, Daher C, Palacios J, Sullivan GD, Bindman AB. Association of health literacy with diabetes outcomes. Journal of the American Medical Association. 2002; 288:475–482. [PubMed: 12132978]

Scott TL, Gazmararian JA, Williams MV, Baker DW. Health literacy and preventive health care use among Medicare enrollees in a managed care organization. Medical Care. 2002; 40:395–404. [PubMed: 11961474]

Sela-Katz P, Rabinowitz I, Shugaev I, Shigorina G. Basic knowledge of the medication regimen correlates with performance on cognitive function tests and diagnosis of dementia in elderly patients referred to a geriatric assessment unit. Gerontology. 2010; 56:491–495. [PubMed: 20339299]

Sherod MG, Griffith HR, Copeland J, Belue K, Krzywanski S, Zamrini EY, Harrell LE, Clark DG, Brockington JC, Powers RE, Marson DC. Neurocognitive predictors of financial capacity across the dementia spectrum: Normal aging, mild cognitive impairment, and Alzheimer's disease. Journal of the International Neuropsychological Society. 2009; 15(2):258–67. [PubMed: 19203439]

Smith, A. Symbol Digit Modalities Test manual—revised. Los Angeles: Western Psychological Services; 1982.

Special Advisory Committee of the Medical Outcomes Trust (SACOT; 2002). Assessing health status and quality-of-life instruments: attributes and review criteria. Quality of Life Research. 11(3):193–205. [PubMed: 12074258]

Sudore RL, Mehta KM, Simonsick EM, Harris TB, Newman AB, Satterfield S, Rosano C, Rooks RN, Rubin SM, Ayonayon HN, Yaffe K. Limited literacy in older people and disparities in health and healthcare access. Journal of the American Geriatrics Society. 2006; 54:770–776. [PubMed: 16696742]

Sudore RL, Yaffe K, Satterfield S, Harris TB, Mehta KM, Simonsick EM, Newman AB, Rosano C, Rooks R, Rubin SM, Ayonayon HN, Schillinger D. Limited literacy and mortality in the elderly: the health, aging, and body composition study. Journal of General Internal Medicine. 2006; 21:806–812. [PubMed: 16881938]

Triebel KL, Martin R, Griffith HR, Marceaux J, Okonkwo OC, Harrell L, Clark D, Brockington J, Bartolucci A, Marson DC. Declining financial capacity in mild cognitive impairment: A 1-year longitudinal study. Neurology. 2009; 73(12):928–934. [PubMed: 19770468]

Wilson RS, Leurgans SE, Boyle PA, Schneider JA, Bennett DA. Neurodegenerative basis of age-related cognitive decline. Neurology. 2010; 75:1070–1078. [PubMed: 20844243]

Wilson RS, Beckett LA, Barnes LL, Schneider JA, Bach J, Evans DA, Bennett DA. Individual differences in rates of change in cognitive abilities of older persons. Psychol Aging. 2002 Jun; 17(2):179–93. [PubMed: 12061405]

Wilson RS, Bienias JL, Berry-Kravis E, Evans DA, Bennett DA. The apolipoprotein E epsilon 2 allele and decline in episodic memory. Journal of Neurology, Neurosurgery and Psychiatry. 2002; 73(6):672–677.

Wolf MS, Curtis LM, Wilson EA, Revelle W, Waite KR, Smith SG, Weintraub S, Borosh B, Rapp DN, Park DC, Deary IC, Baker DW. Literacy, cognitive function, and health: results of the LitCog Study. Journal of General Internal Medicine. 2012; 10:1300–1307. [PubMed: 22566171]

Wolf MS, Gazmararian JA, Baker DW. Health literacy and functional health status among older adults. Archives of Internal Medicine. 2005; 165:1946–1952. [PubMed: 16186463]

Wechsler, D. Wechsler Memory Scale—Revised manual. San Antonio, TX: Psychological Corporation; 1987.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Wood S, Hanoch Y, Barnes A, Liu PJ, Cummings J, Bhattacharya C, Rice T. Numeracy and Medicare Part D: the importance of choice and literacy for numbers in optimizing decision making for Medicare's prescription drug program. Psychology and Aging. 2011; 26:295–307. [PubMed: 21553984]

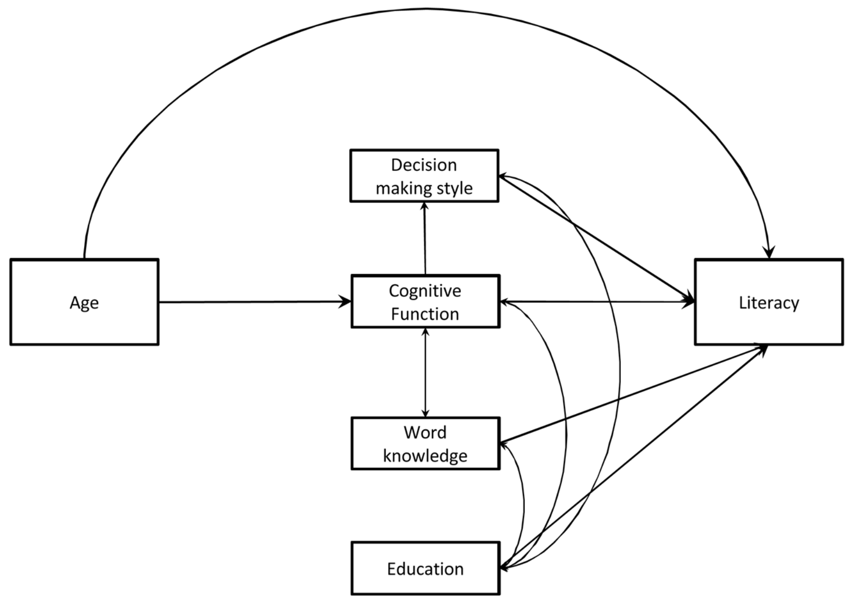

Figure 1.
Proposed conceptual model linking age, cognition and other individual resources with literacy.

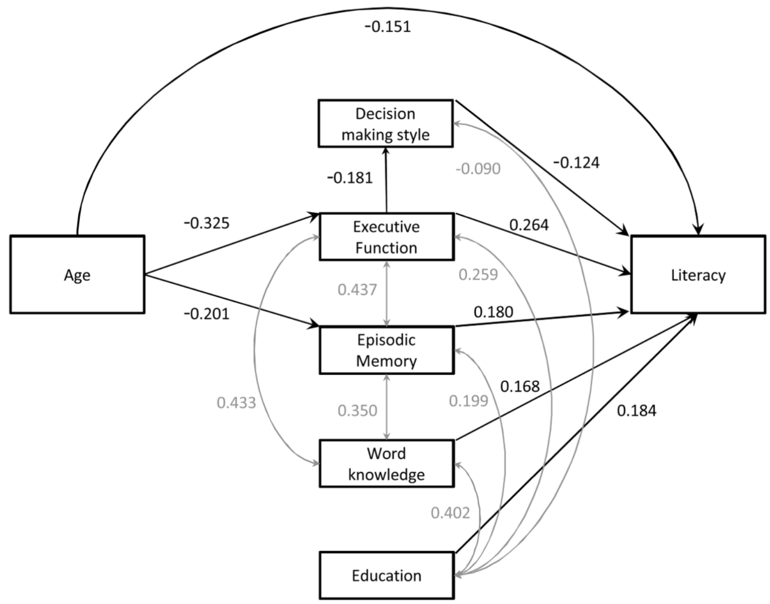

Figure 2.
Results showing path coefficients (black lines) and covariance estimates (grey lines) derived from path analysis.

Table 1

Descriptive properties of the samples included in these analyses

Variable	Cross sectional analyses N=645 Mean (SD) or percent	Longitudinal analyses N=447 Mean (SD) or percent
Age, years	82.2 (7.53) range: 59–101	83.6 (7.4) range: 59–101
Education, years	15.2 (2.95) range: 7–28	15.2 (3.05) range: 7–28
MMSE	28.2 (1.83)	28.12 (1.89)
Women, %	76.7	75.8
Non-Hispanic white, %	91.3	89.0
Literacy (total score)	67% (14.60)	65% (15.0)
Executive function	0.15 (0.63)	0.09 (0.66)
Episodic memory	0.32 (0.71)	0.35 (0.75)
Word knowledge	0.23 (0.63)	0.24 (0.63)
Risk aversion	0.33 (0.30)	0.36 (0.30)

NOTE: SD=Standard deviation. All descriptives provided here are from the time of literacy assessment. Literacy total score is the total percentage correct out of 100, based on the average of the percentages correct in subdomains of health and financial literacy; Executive function is a composite score based on the average of z scores of 9 tests; Episodic memory is a composite score based on the average of z scores of 7 tests; Word knowledge is a composite score based on the average of z scores of 2 tests; Risk aversion is derived from responses across 10 items used to measure risk aversion; please see Methods for details.

Table 2

Intercorrelations among key resource variables (N=645).

	Age	Education	Executive function	Episodic memory	Word knowledge	Risk aversion
Literacy	−0.32**	0.39**	0.54**	0.43**	0.46**	−0.23**
Age		−0.07	−0.36**	−0.23**	−0.10*	0.11*
Education			0.29**	0.22**	0.41**	−0.14*
Executive function				0.52**	0.44**	−0.16**
Episodic memory					0.40**	−0.06
Word knowledge						−0.09£

NOTE: Literacy total score is the total percentage correct out of 100, based on the average of the percentage correct in subdomains of health and financial literacy; Executive function is a composite score based on the average of z scores of 9 tests; Episodic memory is a composite score based on the average of z scores of 7 tests; Word knowledge is a composite score based on the average of z scores of 2 tests; Risk aversion is derived from responses across 10 items used to measure risk aversion.

** $p<0.001$,

* $p<0.01$,

£ $p<0.05$

Table 3

Literacy as a function of cognitive decline

Outcome: Literacy total		
Model terms	**Est (SE)**	**p-value**
Age	−0.003 (0.001)	0.015
Male	0.044 (0.014)	0.002
Education	0.009 (0.002)	<0.001
Starting level of executive function	0.043 (0.012)	<0.001
Stating level of episodic memory	0.015 (0.012)	0.193
Starting level of word knowledge	0.052 (0.012)	<0.001
Risk Aversion	−0.042 (0.019)	0.024
Executive slope	0.546 (0.223)	0.015
Episodic slope	0.755 (0.141)	<0.001
Word knowledge slope	0.425 (0.769)	0.581

NOTE: N=447 persons with longitudinal cognitive data for up to 14 years prior to the literacy assessment (mean=6.4). Est=estimate; SE=standard error. Literacy total score is the total percentage correct out of 100, based on the average of the percentage correct in subdomains of health and financial literacy; Executive function is a composite score based on the average of z scores of 9 tests; Episodic memory is a composite score based on the average of z scores of 7 tests; Word knowledge is a composite score based on the average of z scores of 2 tests; Risk aversion is derived from responses across 10 items used to measure risk aversion. Executive slope, episodic slope, and word knowledge slope were derived from mixed-effects models with a term for time (since baseline in years) to estimate each person's annual rate of cognitive change within each domain; the estimates refer to the increase in literacy associated with a one unit increase in slope (increase=improvement; thus, the positive estimates).