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RESEARCH ARTICLE

Health Literacy, Cognitive Ability, and Functional Health Status among Older Adults

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Objective. To investigate whether previously noted associations between health literacy and functional health status might be explained by cognitive function.

Data Sources/Study Setting. Health Literacy and Cognition in Older Adults ("LitCog," prospective study funded by National Institute on Aging). Data presented are from interviews conducted among 784 adults, ages 55–74 years receiving care at an academic general medicine clinic or one of four federally qualified health centers in Chicago from 2008 to 2010.

Study Design. Study participants completed structured, in-person interviews administered by trained research assistants.

Data Collection. Health literacy was measured using the Test of Functional Health Literacy in Adults, Rapid Estimate of Adult Literacy in Medicine, and Newest Vital Sign. Cognitive function was assessed using measures of long-term and working memory, processing speed, reasoning, and verbal ability. Functional health was assessed with SF-36 physical health summary scale and Patient Reported Outcomes Measurement Information System short form subscales for depression and anxiety.

Principal Findings. All health literacy measures were significantly correlated with all cognitive domains. In multivariable analyses, inadequate health literacy was associated with worse physical health and more depressive symptoms. After adjusting for cognitive abilities, associations between health literacy, physical health, and depressive symptoms were attenuated and no longer significant.

Conclusions. Cognitive function explains a significant proportion of the associations between health literacy, physical health, and depression among older adults. Interventions to reduce literacy disparities in health care should minimize the cognitive burden in behaviors patients must adopt to manage personal health.

Key Words. Health literacy, cognitive abilities, health tasks, patient-reported outcomes, physical health, mental health

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As we approach the third decade of health literacy research, associations between adult literacy skills and health knowledge, self-care ability, health services utilization, clinical outcomes, and mortality have been thoroughly investigated (Baker et al. 1997, 1998, 2008; Kalichman and Rompa 2000; DeWalt et al. 2004; Institute of Medicine 2004; Sudore et al. 2006; Berkman et al. 2011). It is now generally accepted that health literacy, defined by the World Health Organization (WHO) as "the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health," is an important health indicator (WHO 2009). With more than 80 million Americans estimated to have limited health literacy, the challenge in more recent years has been to develop and evaluate effective behavioral and health system interventions designed to mitigate the negative impact of limited health literacy, with particular targets in preventive care and chronic disease management (Institute of Medicine 2004; Sheridan et al. 2011). While a few successes have been reported in the field, there are far more intervention studies that have produced variable results or no improvement in reducing literacy disparities in certain health outcomes such as health comprehension, disease self-management, diabetes control, medication adherence, and hospitalizations. (Davis et al. 1998; Gerber et al. 2005; Pignone et al. 2005; Sheridan et al. 2011). Approaches that have worked tended to be multifaceted (enhanced educational print and media materials, enhanced drug labeling, additional patient education), making it difficult to understand the specific causal mechanisms behind any change in behavior or clinical outcome (Rothman et al. 2004; Pignone et al. 2005; Clement et al. 2009; Sheridan et al. 2011).

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One reason for the lack of progress in identifying effective health literacy interventions is the continued confusion pertaining to the meaning of health literacy. Despite the broad definitions set forth by the WHO and Institute of Medicine (IOM), health literacy is often superficially described and operationalized as reading fluency and numeracy skills, resulting in a limited interpretation of the results provided by available health literacy measures. Thusly, interventions that only simplify written health materials may be inadequately informed. In addition to reading and math, a patient's capacity to manage personal health and make medical decisions likely depends on a broad set of cognitive skills such as the ability to actively process, remember, and apply learned information in a variety of health contexts (Wolf et al. 2009). Therefore, it is essential to clarify what it means for a patient to have "limited health literacy" in the context of his or her cognitive abilities to gain a robust conceptual understanding of the problem and to guide intervention strategies.

In addition to affecting health comprehension and outcomes, health literacy has been shown to be associated with health status (Cho et al. 2008; Bennett et al. 2009). A previous study conducted by this group among a large sample of Medicare enrollees noted significant relationships between health literacy and self-rated physical and mental health (Wolf, Gazmararian, and Baker 2005). A parallel body of research similar to health literacy studies has also repeatedly documented associations between a range of cognitive skills—including aspects of memory, processing speed, and reasoning, with medication adherence, clinical outcomes, and physical and mental health (Whalley and Deary 2001; Stilley et al. 2004; Batty et al. 2005; Singh-Manoux et al. 2005; Insel et al. 2006; Shipley et al. 2006). Recently, a small number of investigations have reported strong ties between cognitive function and the most common health literacy measures (Baker et al. 2008; Levinthal et al. 2008; Federman et al. 2009; Wolf et al. 2009).

As a follow-up to an earlier study by our team, which documented the impact of limited health literacy on functional health status, we performed a similar investigation in a new cohort from the National Institute of Aging study of Health Literacy and Cognition in older adults (LitCog, R01 AG030611), this time including measures of cognitive function (Grober, Sliwinsk, and Korey 1991; Wolf, Gazmararian, and Baker 2005; Wolf et al. 2012). Our objective was to examine the extent to which cognitive function could explain the previously noted relationship between health literacy and physical and mental health.

METHODS

The study cohort and methods of the LitCog study have been described in detail previously, and also explained below (Wolf et al. 2012).

Sample

English-speaking adults aged 55–74 years who received care at an academic general internal medicine clinic or one of four federally qualified health centers in Chicago were recruited from August 2008 through October 2010. In brief, 3,176 age-eligible patients were identified through electronic health records, and 1,884 were reached via phone and invited to participate. Patients were deemed ineligible due to severe cognitive or hearing impairment, limited English proficiency, or not being connected to a clinic physician (defined as <2 visits in 2 years) (n = 244). In addition, 794 refused, 14 were deceased, and 28 had scheduling conflicts. The final study sample consisted of 832 participants, with an overall cooperation rate of 51 percent (American Association for Public Opinion Research 2004).

Procedure

Subjects completed two structured interviews, 7–10 days apart, each lasting 2.5 hours. A trained research assistant guided patients through a series of assessments that, on Day 1, included self-reported basic demographics, socioeconomic status, number of chronic conditions, and number of medications. In addition, functional health status and health literacy measures were administered. On Day 2, patients were given a cognitive battery to measure processing speed, working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability (Ekstrom, French, and Harman 1976; Raven 1976; Zachary 1986; Grober, Sliwinsk, and Korey 1991; Salthouse and Babcock 1991; Salthouse 1992; Cherry and Park 1993; Robbins et al. 1994; Park et al. 1997; Kluger et al. 1999; Smith 2000). With the exception of verbal ability, all tests were independent of reading skills. Multiple tests were used for each cognitive domain, allowing a latent trait to be extracted. Northwestern University's Institutional Review Board approved the study.

Measures

Health Literacy. Health literacy was assessed by the Test of Functional Health Literacy in Adults (TOFHLA), Rapid Estimate of Adult Literacy in Medicine (REALM), and the Newest Vital Sign (NVS) (Davis et al. 1993; Parker et al. 1995; Weiss et al. 2005). The TOFHLA and REALM are the most commonly used measures of literacy in health care research (Institute of Medicine 2009). The TOFHLA emphasizes the use of materials patients likely encounter in health care to test reading fluency (Parker et al. 1995). Total scores range from 0 to 100 and are classified as inadequate (0–59), marginal (60–74), or adequate (75–100). The REALM is a word-recognition test consisting of 66 health-related words arranged in order of increasing difficulty (Davis et al. 1993). Patients read aloud as many words as they can and scores are based on the total number of words pronounced correctly. Dictionary pronunciation is the scoring standard and interpreted as low (0–44), marginal (45–60), or adequate (61–66). Finally, the NVS is a screening tool used to determine risk for limited health literacy (Weiss et al. 2005). Patients are given a copy of a nutrition label and asked six questions about how to interpret and act on the information. Scores are classified as high likelihood (0–1) or possibility (2–3) of limited literacy, and adequate literacy (4–6).

Cognitive Abilities. A comprehensive battery of tests was used to assess six different cognitive domains, which included processing speed (Salthouse and Babcock 1991; Salthouse 1992; Smith 2000), working memory (Cherry and Park 1993; Robbins et al. 1994), inductive reasoning (Ekstrom, French, and Harman 1976; Raven 1976; Robbins et al. 1994), long-term memory (Robbins et al. 1994; Kluger et al. 1999), prospective memory (Park et al. 1997), and verbal ability (Zachary 1986; Grober, Sliwinsk, and Korey 1991; Robbins et al. 1994). Verbal ability was classified as crystallized ability, measuring an individual's prior acquired knowledge. The other five cognitive traits (processing speed, working memory, inductive reasoning, long-term memory, and prospective memory) were considered fluid abilities, as all are associated with active information processing.

Functional Health Status. Physical function was assessed using the SF-36 physical health summary subscale. The SF-36 consists of 36 items and eight weighted subscales with scores transformed from 0 to 100, with higher scores indicating better function. The scores are standardized so that the U.S. population mean has a score of 50 (U.S. Population Norms 2013; Ware 1994). Anxiety and depression were measured using the Patient Reported Outcomes Measurement Information Service (PROMIS) short form subscales (Cella et al. 2007; Reeve et al. 2007). The scores range from 8 to 40 for depression and from 7 to 35 for anxiety, with higher scores indicating more depression and anxiety, respectively.

Analysis Plan

Descriptive statistics were calculated for each variable. ANOVA was used to compare mean performance on health tasks and functional health status by health literacy categories. Pearson product-moment (TOFHLA, REALM) and Spearman (NVS) correlations were used to examine associations between health literacy measures and cognitive tests. Fluid and crystallized ability scores were created to reduce the six cognitive categories to two and to avoid multicollinearity in subsequent regression models. Prior latent trait analyses performed in the previous study classified verbal ability alone as crystallized ability, whereas all others were factored into the fluid ability score (Wolf et al. 2012). Univariate imputation sampling methods were used to estimate any missing values (n = 98) on cognitive measures by regressing each variable on age and variables from the same cognitive domain (i.e., processing speed, working memory, inductive reasoning, long-term memory, verbal ability) in a bootstrapped sample of nonmissing observations. Fluid and crystallized ability summary scores were then calculated by estimating a single factor score for both fluid and crystallized abilities, with maximum likelihood estimation.

To examine the independent associations between health literacy and fluid or crystallized cognitive abilities with health status, we used five separate multivariable linear regression models for each combination of outcome and health literacy. There were complete data for all cognitive tests on 784 patients, which was the sample size used for multivariable analyses. Age, gender, race, and number of comorbid chronic conditions were included in all models as covariates. Model 1 included health literacy; model 2 included fluid ability; model 3 included crystallized ability; model 4 included both fluid ability and crystallized ability. Model 5 included health literacy, fluid ability, and crystallized ability to evaluate the extent to which the effect of health literacy was attenuated by cognitive abilities. The Vuong test, a likelihood-ratio based approach for non-nested models, was used to determine whether the variance explained by the models (R^2) significantly changed when health literacy, fluid abilities, or crystallized abilities were included or omitted (Vuong 1989). Analyses were performed using STATA version 11.2 (College Station, TX, USA).

RESULTS

Of the 832 participants in the study sample, 784 (94 percent) had complete data for the literacy and cognitive measures and, therefore, were used in these analyses. Table 1 contains the demographic and clinical characteristics for these participants. The sample was socially, racially, and economically diverse. The mean age was 63.1 (±5.5) years, 68.4 percent of participants were female, and 50.7 percent were white. On average, individuals had two chronic conditions (M = 1.9, SD = 1.4) and were taking 3.6 prescription medications (SD = 3.1). Based on normative data from the SF-36 and PROMIS measures, their physical and mental health scores (anxiety, depression) were considered average (Ware 1994; Cella et al. 2007).

A total of 16.8 and 12.5 percent of the participants had marginal and inadequate health literacy, respectively, as measured by the TOFHLA; 15.4 and 8.9 percent by the REALM; and 22.9 and 28.9 percent by the NVS. As previously reported, the following correlations were noted among the three health literacy measures: 0.76 (TOFHLA-REALM), 0.62 (TOFHLA-NVS), and 0.47 (NVS-REALM; all $p < .001$). Health literacy measures were strongly correlated with all cognitive abilities. Fluid abilities were more strongly correlated with the TOFHLA and NVS than with the REALM (0.76 and 0.73 vs. 0.57, respectively), and crystallized abilities correlated similarly with all health literacy measures (TOFHLA: 0.77, REALM: 0.74, NVS: 0.71). Fluid and crystallized abilities were strongly correlated with one another ($r = 0.78$) (Wolf et al. 2012).

Table 2 demonstrates the associations between health literacy and functional health status. In bivariate analyses, higher scores on the three health literacy measures were strongly correlated with better physical function, less depression, and less anxiety (all $p < .001$), with the exception of the REALM, which did not correlate with anxiety.

In multivariate models (Table 3), inadequate health literacy as measured by the TOFHLA was independently associated with worse physical function and greater depression, but not anxiety, after controlling for covariates ($\beta = -5.9$, 95 percent CI: −9.3 to −2.5, $p < .001$; $\beta = 2.8$, 95 percent CI: 1.5–4.2, $p < .001$; $\beta = 1.1$, 95 percent CI: −0.2 to 2.4, $p = .09$, respectively). Weaker fluid cognitive abilities were also significantly associated with poorer

Table 1: Baseline Characteristics of Sample ($N = 784$)

Variable	*Summary Value*
Age, mean (SD)	63.1 (5.5)
Gender (%)	
Female	68.4
Race (%)	
Black	42.2
White	50.7
Other	7.1
Education (%)	
High school or less	26.4
Some college or technical school	21.9
College graduate	20.8
Graduate degree	30.9
Income (%)	
<$10,000	11.9
$10,000–$24,999	19.0
$25,000–$49,999	15.5
>$50,000	53.6
Employment status (%)	
Full-time	20.7
Part-time	15.1
Not working	64.2
Marital status (%)	
Married	44.8
Not married	55.2
Living situation (%)	
Own	62.7
Rent	33.1
Live with relatives or friends	3.7
Chronic conditions (%)	
Hypertension	59.5
Diabetes	15.4
Coronary artery disease	6.5
Heart failure	4.6
Bronchitis or emphysema	12.9
Asthma	18.5
Arthritis	47.1
Cancer	7.3
Depression	19.6
Total number, mean (SD)	1.9 (1.4)
Number of prescription medications, mean (SD)	3.6 (3.1)
Functional health status	
Physical (0–100)	82.3 (17.4)
Depression (8–40)	12.9 (6.1)
Anxiety (7–35)	15.2 (5.8)

Table 2: Associations between Health Literacy Measures and Functional Health Status

	Health Literacy			
Health Status	*Adequate Mean ± SD*	*Marginal Mean ± SD*	*Inadequate Mean ± SD*	
TOFHLA				
Physical function	85.3 ± 15.4	77.9 ± 19.3	71.0 ± 19.7	<0.001
Depression	12.2 ± 5.3	13.6 ± 6.7	16.3 ± 7.7	<0.001
Anxiety	14.9 ± 5.6	15.3 ± 5.9	16.7 ± 6.1	0.02
REALM				
Physical function	84.5 ± 16.2	77.7 ± 17.9	71.2 ± 20.4	<0.001
Depression	12.4 ± 5.7	14.1 ± 6.7	14.9 ± 7.4	<0.001
Anxiety	15.0 ± 5.7	15.7 ± 5.8	15.6 ± 5.9	0.39
NVS				
Physical function	87.0 ± 14.2	81.8 ± 17.4	74.6 ± 19.4	<0.001
Depression	11.8 ± 5.0	12.6 ± 5.6	15.0 ± 7.4	<0.001
Anxiety	14.6 ± 5.7	15.0 ± 5.6	16.3 ± 5.9	0.003

Higher score for physical function = better physical function (range 0–100); higher score for depression = increased depression (range 8–40); higher score for anxiety = increased anxiety (range 7–35).

physical and mental health ($\beta = 2.5$, 95 percent CI: 1.2–3.8, $p < .001$; $\beta = -1.4$, 95 percent CI: −1.9 to −0.9, $p < .001$; $\beta = -0.8$, 95 percent CI: −1.3 to −0.3, $p = .002$, respectively). Crystallized cognitive abilities were associated with physical health and depression, but not anxiety ($\beta = 2.0$, 95 percent CI: 0.7–3.4, $p = .003$; $\beta = -0.9$, 95 percent CI: −1.4 to −0.4, $p = .001$; $\beta = -0.3$, 95 percent CI: −0.9 to 0.2, $p = .19$, respectively). When fluid and crystallized cognitive abilities were entered in multivariable models in addition to health literacy, the relationship between health literacy and physical health was attenuated by 42.4 percent and no longer significant ($\beta = -3.4$, 95 percent CI: −8.0 to 1.1, $p = .14$). For depression, the association with health literacy was attenuated by 46.5 percent after fluid and crystallized abilities were entered into the model, and no longer statistically significant ($\beta = 1.5$, 95 percent CI: −0.2 to 3.2, $p = .09$).

Health literacy as measured by the REALM (Table S1) was only significantly associated with physical health while health literacy as measured by the NVS was an independent predictor of physical health, depression, and anxiety (Table S2). After including health literacy, fluid cognitive abilities, and crystallized cognitive abilities in the models, the association between health literacy as measured by the REALM and NVS and physical health were attenuated by

Table 3: Multivariable Models of Health Literacy, Cognitive Abilities, and Health Status

	Model 1		*Model 2*		*Model 3*		*Model 4*		*Model 5*	
	HL Only		*FA Only*		*CA Only*		*FA + CA*		*HL + FA + CA*	
Variable	*β (95% CI)*	*p*	*β (95% CI)*	*p*	*β (95% CI)*	*p*	*β (95% CI)*	*p*	*β (95% CI)*	*p*
Physical Health										
Inadequate Health literacy	−5.9 (−9.3, −2.5)	0.001	—		—		—		−3.4 (−8.0, 1.1)	0.14
Fluid abilities	—		2.5 (1.2, 3.8)	<0.001	—		2.1 (0.3, 3.9)	0.02	1.8 (−0.1, 3.7)	0.07
Crystallized abilities	—		—		2.0 (0.7, 3.4)	0.003	0.6 (−1.2, 2.4)	0.51	−0.02 (−2.0, 2.0)	0.98
Adjusted R^2	0.35		0.35		0.34		0.35		0.35	
Depression										
Inadequate Health literacy	2.8 (1.5, 4.2)	<0.001	—		—		—		1.5 (−0.2, 3.2)	0.09
Fluid abilities	—		−1.4 (−1.9, −0.9)	<0.001	—		−1.4 (−2.1, −0.7)	<0.001	−1.3 (−2.1, −0.6)	<0.001
Crystallized Abilities	—		—		−0.9 (−1.4, −0.4)	0.001	0.1 (−0.6, 0.8)	0.85	0.3 (−0.4, 1.1)	0.38
Adjusted R^2	0.19		0.20		0.19		0.20		0.20	
Anxiety										
Inadequate Health literacy	1.1 (−0.2, 2.4)	0.09	—		—		—		0.2 (−1.5, 2.0)	0.79
Fluid abilities	—		−0.8 (−1.3, −0.3)	0.002	—		−1.0 (−1.7, −0.4)	0.003	−1.1 (−1.8, −0.3)	0.004
Crystallized abilities	—		—		−0.3 (−0.9, 0.2)	0.19	0.4 (−0.3, 1.1)	0.30	0.4 (−0.3, 1.2)	0.29
Adjusted R^2	0.13		0.13		0.12		0.13		0.13	

Fluid abilities are cognitive traits associated with active information processing; crystallized abilities are prior knowledge. All models include the covariates of age, gender, race/ethnicity, and number of comorbid conditions. CA, crystallized ability; FA, fluid abilities; HL, health literacy.

72.3 and 34.6 percent, respectively. In the final model, the relationship between health literacy as measured by the NVS and depression was reduced by 50.0 percent and also became nonsignificant (without cognitive abilities: $\beta = 2.4$, 95 percent CI: 1.3–3.5, $p < .01$; with cognitive abilities: $\beta = 1.2$, 95 percent CI: −0.2 to 2.5, $p = .09$).

The NVS was the only health literacy measure linked to anxiety in multivariate models; this association was reduced and no longer significant after including fluid and crystallized abilities in the model (without cognitive abilities: $\beta = 1.4$, 95 percent CI: 0.3–2.4, $p = .01$; with cognitive abilities: $\beta = 0.8$, 95 percent CI: −0.5 to 2.1, $p = .24$). The inclusion or omission of fluid or crystallized cognitive abilities did not significantly alter the explanatory power (adjusted R^2) of the multivariable models for health literacy (as measured by TOFHLA, REALM, or NVS) and functional health status.

Discussion

Low health literacy, as assessed by the TOFHLA, REALM, and NVS, has repeatedly been found to be a strong risk factor for inadequate health knowledge, poorer self-care ability, greater morbidity, and mortality as well as lower self-reported health (Baker et al. 1997, 1998, 2008; DeWalt et al. 2004; Cho et al. 2008; Bennett et al. 2009; Berkman et al. 2011). We were able to replicate this group's previous research findings in a separate cohort by showing strong associations between the three common measures of health literacy and physical and mental health status (Wolf, Gazmararian, and Baker 2005). Furthermore, each of these relatively crude assessments (of reading ability and numeracy skills) were strongly correlated with tests of crystallized and fluid cognitive abilities, as previously noted by Federman and recently published by our group (Federman et al. 2009; Wolf et al. 2012). However, evidence from multivariable models suggests that health literacy, as measured by these tests, is largely representative of cognitive function. Significant associations between health literacy and physical and mental health were substantially attenuated after adjusting for cognitive function, becoming nonsignificant.

It is intuitive that health literacy, as measured by the TOFHLA, REALM, and NVS, reflects a cognitive skill set. Reading ability, in the process of decoding and comprehending text, is dependent upon basic fluid and crystallized cognitive abilities. Numeracy skills require working memory, processing speed, and reasoning (among others) to perform calculations. Yet our results show that additional abilities beyond just reading and numeracy are likely to be very important to health. This is logical when considering the patient's role in maintaining personal health, especially in the presence of chronic conditions. An individual must engage in active problem-solving to successfully navigate a health system, recall doctor instructions, dose out multi-drug regimens, comprehend health insurance information, and maintain daily health-promoting behaviors. Failure to engage in healthy behaviors can lead to worse health outcomes, poorer self-rated health, increased depression, and anxiety. While reading and numeracy skills are essential for disease self-management, broader cognitive abilities are also required. This was evidenced by our models, which had the greatest explanatory power for functional health status when both health literacy and cognitive function were included. These results have important implications for health literacy research. Specifically, to move beyond an agenda focused predominantly on providing plain language information following evidence-based principles for content and format, we need to better understand how to simplify patients' daily tasks in disease self-management.

Perhaps the most significant message from our findings is that the current definition of health literacy, as defined either by the WHO or Institute of Medicine, must be appropriately conceptualized rather than redefined. It is clear through past intervention attempts that the problem of limited health literacy can often be superficially interpreted; based on the false premise that individual differences are based solely on reading and math skills (Wolf et al. 2009). If health literacy is a broad cognitive skill set as both the WHO and IOM definitions imply, then interventions should reflect this.

In addition to education initiatives, human factors-related strategies for addressing health care complexity may mitigate patients' cognitive burden in managing personal health. Such system-targeted interventions could address both demands on fluid and crystallized abilities. For example, to minimize demands on fluid abilities, delivering information via tangible means such as in print or via web, may allow the patients to review the information as needed after the medical encounter is over, enhancing retention of information and relying less on inference. Making health information and medical instruction readily available across modalities, while using care coordinators or patient navigators, could ease the burden on patients' fluid and crystallized cognitive skills. For example, providing explicit dosing instructions for drug regimens that do not require patients to "do the math" (i.e., take two pills in the morning and two pills in the evening vs. take two pills twice daily) has been shown to improve medication use (Wolf et al. 2011a,b). Going one step further, extended release and combination pills that reduce the complexity of patients' drug regimens have been shown in studies to improve adherence and clinical outcomes (Blum, Havlik, and Morganroth 1976; Dezii 2000; Simpson et al. 2006; Benner et al. 2009). Looking to the future, these strategies will be particularly salient given the patients' increased use of the Internet to access patient portals, mobile health technology, and electronic medical records (Bates and Bitton 2010; Chumbler, Haggstrom, and Saleem 2011). Recent studies have highlighted the complexity and difficulty experienced by older adults when navigating a health care website or patient portal; future interventions may be designed to address these issues and also incorporate designated staff to educate and continually monitor patient access and use of services (Czaja, Sharit, and Nair 2008). While there are many affordances to the increasingly available electronic tools to help promote health maintenance and safe medication use, it is important that patients find them well-designed and easy to navigate. Moreover, where many recent, usually multifaceted strategies have been proven efficacious at improving patient knowledge and behavior, future evaluations should specifically determine whether disparities in performance by literacy and/or cognitive skill are reduced. This would truly demonstrate that the cognitive load has been minimized.

This study has a number of limitations that should be considered in the interpretation of the results. We examined a population of older adults receiving treatment at internal medicine clinics in the Chicago area who are fluent in English and predominantly female. Our sample may be limited in generalizability given our moderate cooperation rate, recruitment from primary care practices in one urban area, and older adult population. Thus, results may not be generalizable, especially to younger patients. Although participants were recruited from multiple study sites, the sample is cross-sectional and causality cannot be established with this study design. Specifically, we cannot completely separate whether low cognitive ability or limited health literacy caused worse health outcomes, or whether worse health outcomes resulted in impaired cognition and literacy. Currently, the LitCog study does include prospective, follow-up interviews every 3 years, and future research will be able to better examine the relationship between cognitive function and health literacy.

In summary, health literacy remains an important construct that encapsulates an individual's skill set to manage health, a preponderance of which is related to cognitive function. This includes memory, processing speed, problem-solving, attained health knowledge, as well as reading and numeracy skills. Interventions to overcome health literacy disparities, therefore, must deconstruct the specific tasks performed by patients by considering how various cognitive factors contribute to the difficulty of the task to improve performance. A consideration worthy of future studies is whether the current common measures of health literacy (TOFHLA, REALM, NVS) are adequate given the sizable body of literature supporting their predictive ability, or whether more comprehensive assessments could better identify and categorize health literacy problems—both for research and clinical purposes. Yet even if better screening tools become available that can accurately identify those at risk of limited health literacy and the nature of the problem(s), our research agenda may be more informative in terms of understanding how health systems can lessen the cognitive burden placed on patients by redesigning patient roles. Moving forward, additional prospective studies of health literacy and cognitive function should be conducted to more fully elucidate these relationships in various patient populations and among a more extensive list of health outcomes. In this manner, the knowledge gained can provide health systems with explicit guidance on how to reduce health care complexity while identifying individuals who may require additional assistance when engaging health care providers and services.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Table S1: Multivariable Models of Health Literacy (REALM), Cognitive Abilities, and Physical and Mental Health.

Table S2: Multivariable Models of Health Literacy (NVS), Cognitive Abilities, and Physical and Mental Health.

Appendix SA1: Author Matrix.