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Research Article

Cognition and Health Literacy in Older Adults' Recall of Self-Care Information

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Abstract

Purpose of the Study: Health literacy is associated with health outcomes presumably because it influences the understanding of information needed for self-care. However, little is known about the language comprehension mechanisms that underpin health literacy.

Design and Methods: We explored the relationship between a commonly used measure of health literacy (Short Test of Functional Health Literacy in Adults [STOFHLA]) and comprehension of health information among 145 older adults.

Results: Results showed that performance on the STOFHLA was associated with recall of health information. Consistent with the Process-Knowledge Model of Health Literacy, mediation analysis showed that both processing capacity and knowledge mediated the association between health literacy and recall of health information. In addition, knowledge moderated the effects of processing capacity limits, such that processing capacity was less likely to be associated with recall for older adults with higher levels of knowledge.

Implications: These findings suggest that knowledge contributes to health literacy and can compensate for deficits in processing capacity to support comprehension of health information among older adults. The implications of these findings for improving patient education materials for older adults with inadequate health literacy are discussed.

Keywords: Health literacy, Reading comprehension, Domain-specific knowledge

Health literacy, often defined as the ability to find, understand, and use the information needed to make health care decisions (U.S. Department of Health and Human Services, 2000), is a crucial challenge for our national health care system. Parker, Wolf, and Kirsh (2008) described this challenge as a "perfect storm," with an aging population that has inadequate health literacy confronting an increasingly fragmented and consumer-driven health care system that puts a premium on patient autonomy. Many older adult patients who must manage chronic illness experience age-related declines in the health literacy–related abilities required for complex self-care tasks such as managing medication regimens or comprehending complex treatment information, but they do not receive adequate support from their health care system (e.g., Jansen et al., 2008; Paasche-Orlow, Schillinger, Greene, & Wagner, 2006; Wolf, Gazmararian, & Baker, 2005).

The health literacy challenge is reflected in mounting evidence linking health literacy measures such as the Rapid

Estimate of Adult Literacy in Medicine (REALM; Davis et al., 1993) and the Short Test of Functional Health Literacy in Adults (STOFHLA; Baker, Williams, Parker, Gazmararian, & Nurss, 1999) to health behaviors (e.g., adherence to instructions), health service utilization (e.g., emergency department visits), and outcomes among older adults with chronic illness (for reviews, DeWalt, Berkman, Sheridan, Lohr, & Pignone, 2004; Wolf et al., 2005). Although performance on these tests is assumed to be a proxy for a variety of abilities and skills that underpin health behaviors and outcomes (e.g., DeWalt & Pignone, 2005; Morrow et al., 2006), little is known about these psychological mechanisms.

Health literacy has been conceptualized from a variety of theoretical frameworks (Berkman, Davis, & McCormack, 2010). It has often been viewed functionally as the patient resources (such as their motivations, illness experience, sensory and cognitive abilities) needed to manage their health demands, such as taking medications (Baker, 2006; Nielsen-Bohlman, Panzer, & Kindig, 2004). Process-based models of health literacy focus on how these patient resources influence the ability to understand the information needed to perform self-care and other health care tasks (e.g., Baker, 2006; Wolf et al., 2009). These models are helpful for developing educational and other interventions to support health behaviors and enhance outcomes among older adults with inadequate health literacy.

The Process-Knowledge (P-K) model was developed to identify the abilities that underpin health literacy by contextualizing the concept of health literacy in terms of theories of discourse comprehension across the life span (Chin et al., 2011). This framework assumes that health texts that, for example, provide an explanation of illness or describe how to take medication, are understood at multiple levels—a surface representation of recognizing words, a textbase representation of the meaning directly conveyed by the message, and a mental model of the situation described by the message (Kintsch, 1998). These comprehension processes in turn depend on cognitive resources that have different age-related trajectories.

Processing capacity (e.g., processing speed, working memory) constrains the efficiency of many comprehension processes and thus the fidelity of the text representations. Readers with less working memory capacity are less able to keep concepts readily accessible to be integrated into propositions (Kintsch, 1998). Processing capacity tends to decline with age, and age differences in processing capacity are associated with differences in comprehension and learning (Beier & Ackerman, 2005; Horn & Cattell, 1967). For example, processing capacity declines can undermine conceptual integration in creating textbase representations (e.g., Stine-Morrow & Miller, 2009).

General knowledge (i.e., linguistic/verbal knowledge, or crystallized ability) and domain-specific knowledge, on the other hand, often support comprehension processes. More knowledgeable readers recognize words more quickly and are better able to integrate the associated concepts into the textbase (Chin et al., 2015; Payne, Gao, Noh, Anderson, & Stine-Morrow, 2012). Although processing capacity declines with age, knowledge tends to increase or remain invariant (Horn & Cattell, 1967; Li et al., 2004), depending on literacy (Stanovich, West, & Harrison, 1995) and domain-specific (Beier & Ackerman, 2005; Chin et al., 2009) experience. Although declining capacity impairs comprehension processes, age-related knowledge gains can streamline these processes so that they depend less on processing capacity. For example, Payne and colleagues (2012) found that literacy experience (as measured by print exposure) can offset the impact of age-related decline in working memory on sentence recall, so that the recall performance of older adults with more print exposure was less influenced by working memory differences. Hence, knowledge may be especially important for health literacy because knowledge about health may be more malleable than processing capacity and can increase with age-related growth in experience, learning, and education. Knowledge is potentially an age-based asset that can promote health literacy and thereby behaviors and outcomes.

The P-K model is supported by evidence showing links between processing capacity and health literacy. For example, processing capacity measures contribute to individual differences in performance on health literacy measures, such as the REALM and STOFHLA (Chin et al., 2011; Federman, Sano, Wolf, Siu, & Halm, 2009; Levinthal et al., 2008; Morrow et al., 2006), and account for a large amount of education-related variance in performance. The model also suggests that the reason that health literacy measures are predictive of health behaviors and outcomes is that such measures reflect broader abilities related to processing capacity and knowledge. In one of the few studies to investigate this prediction, Wolf and colleagues (2012) used a regression approach to show that processing capacity measures explain health literacy–related differences on tasks that require understanding and remembering health information, suggesting that literacy's impact on health depends on broader cognitive ability.

The P-K model also focuses on the potential of knowledge to offset age-related processing capacity limits in order to support health literacy, decisions, and behaviors. Knowledge improves performance on the REALM and STOFHLA tests (Chin et al., 2011) as well as comprehension of health information (Chin et al., 2015; Miller, Stine-Morrow, Kirkorian, & Conroy, 2004). Wolf and colleagues (2012) found that measures of general knowledge, as measured by vocabulary, partially contributed to the impact of health literacy on understanding and remembering health information. A few studies have attempted to tease apart the effects of domain-general versus domain-specific knowledge (Beier & Ackerman, 2005; Chin et al., 2015). However, the relative contributions of general knowledge, domain-specific (health) knowledge, processing capacity, and their interactions with health behaviors have not been established.

Because understanding and remembering health information is an important step in health management, we examined the influence of health literacy on recall of health information among older adults, and how the relationship between health literacy and recall is mediated by processing capacity, and both general and health knowledge. We focused on hypertension because it is one of the most prevalent chronic illnesses among older adults (American Heart Association Statistics Committee and Stroke Statistics Subcommittee, 2013) and because of evidence that limited knowledge undermines self-care among older adults with this illness (e.g., Leventhal, Safer, & Panagis, 1983). Although we did not investigate health behaviors and outcomes directly, comprehension of health information is a critical first step for patients to be able to implement and manage their self-care behavior. Comprehension and recall of health information have been found to predict self-care behavior (e.g., among diabetics, memory for medication regimens predicts A1C levels, an indicator of how well diabetes is controlled; McPherson, Smith, Powers, & Zuckerman, 2008; also see Metlay et al., 2008). We examined the following questions related to health literacy and recall of health information among older adults with hypertension: (a) Does health literacy (measured by STOFHLA) predict the recall of health information? (b) Is the relationship between health literacy and recall explained or mediated by knowledge (both general and health) and processing capacity measures? (c) Do processing capacity and knowledge abilities (including general and health) interact to influence recall, such that processing capacity has less impact on recall among older adults with more versus less knowledge?

Methods

Participants

One hundred and forty-nine older adults were recruited from a small urban community in central Illinois (see Table 1). Participants were screened for normal vision, native English-language proficiency, and conditions that might impair cognitive function (i.e., stroke or cancer treatment). Four were excluded from analyses because of incomplete data, resulting in a sample of 145 participants (93 females and 52 males). Participants' hypertension status was self-reported by responding to the question "Have you ever been told by a doctor or health professional that you have high blood pressure (also called hypertension)?" About half (52.4%) of the participants self-reported a diagnosis of hypertension. Although participants without hypertension had slightly higher education than participants with hypertension (with hypertension: mean = 15.08 years; without hypertension: mean = 16.35 years; $t(142) = 2.89$, $p < .01$), participants with and without hypertension did not differ on the hypertension knowledge ($t(143) = 0.07$, $p = .94$) or the STOFHLA ($t(143) = -1.56$, $p = .12$) measures.

Table 1. Descriptive Statistics of the Participants

	Mean (*SD*)
Age (years)	70.52 (7.88)
Education (years)	15.68 (2.69)
Letter comparison (max score = 21; Salthouse, 1991)	8.21 (2.43)
Pattern comparison (max score = 30; Salthouse, 1991)	15.29 (3.39)
Hidden pattern (max score = 100; Ekstrom et al., 1976)	40.47 (16.33)
Card rotation (max score = 80; Ekstrom et al., 1976)	42.43 (15.93)
Letter number sequencing (max score = 21; Wechsler, 1997)	9.74 (2.56)
Advanced vocabulary (max score = 18; Ekstrom et al., 1976)	9.90 (4.49)
Health knowledge (max score = 37; Chin et al.,2009)	30.08 (2.90)
STOFHLA (max score = 36; Baker et al., 1999)	34.50 (2.11)

Note: STOFHLA = Short Test of Functional Health Literacy in Adults.

Measures

Processing Capacity

Five measures of processing capacity were used. Processing speed was measured by the Letter Comparison and Pattern Comparison tests (Salthouse, 1991). Spatial abilities were measured by Hidden Pattern and Card Rotation tests (Ekstrom, French, Harmon, & Dermen, 1976). Working memory was measured by the Letter Number Sequencing test (Wechsler, 1997).

General Knowledge

General knowledge (i.e., crystallized ability) was measured by the Advanced Vocabulary Task (Ekstrom et al., 1976).

Domain-Specific Knowledge

Domain-specific knowledge about health was measured as factual knowledge about hypertension using the Hypertension Knowledge Questionnaire (Cronbach's alpha = .90; Chin et al., 2009). This measure consists of 33 true/false (T/F) questions and 4 multiple-choice questions, including probes about the definition and consequences of hypertension, as well as questions about self-care (e.g., "Exercising every day may make blood pressure go down." [True]; "For a blood pressure reading of 120/80, the number 80 is the systolic blood pressure." [False]).

Health Literacy

Participants' health literacy was evaluated by the STOFHLA (Baker et al., 1999), which consists of two brief health care passages describing x-ray preparation and Medicaid information. The passages consisted of 15 sentences from which 36 words were missing. Participants had to select the best response from four choices to complete each sentence.

Performance on this test was high (mean = 34.5, *SD* = 2.1, min = 20, max = 36), reflecting the high level of education of the sample (e.g., Morrow et al., 2006). Because of this restricted range in scores, we likely underestimated the impact of health literacy on recall.

Health Passages

Participants read nine hypertension-related passages created from information obtained from reputable Web sites (e.g., NIH, AHA). All the passages described self-care behavior for patients with hypertension. The information about self-care was elaborated with a rationale for engaging in the self-care behavior and/or details about how this self-care behavior might be managed. Mean passage length was 7.3 sentences (*SD* = 1.3) and 116.8 words (*SD* = 11.4). The mean passage Flesch Reading Ease score was 61.2 (*SD* = 7.9) and mean passage Flesch–Kincaid Grade Level was 8.6 (*SD* = 1.5). An example passage is presented in Figure 1.

Passage Recall

Memory for the passages was measured by a fill-in-the-blank cued recall task that consisted of 35 questions with 50 blanks. Recall scores were the proportion of correct responses out of 50 items. The questions were developed to test memory for key concepts in the passages with good internal reliability (Cronbach's alpha = .83). Items consisted of either a sentence that contained 1–4 blanks that were completed to make a coherent sentence or were questions where the blanks were the response. They tested memory for explicit information in the passages or memory for relationships between concepts in the passage. For example, "You can reduce high blood pressure by eating foods low in ______ and ______." or "What are the symptoms of high blood pressure? __________." Each passage was probed by an average of 3.9 questions (*SD* = 0.8) and 5.6 blanks (*SD* = 1.7) in the delayed recall task. None of the recall questions duplicated items on the Hypertension Knowledge Questionnaire.

To control high blood pressure, monitoring blood pressure at home can be a helpful addition to regular monitoring in a healthcare provider's office. This is because a single measurement taken at the doctor's office is like a snapshot. It tells what your blood pressure is at that moment, rather than what it is over time. Since there are no symptoms for high blood pressure and no way to feel changes in blood pressure, measuring is the only way to know for sure. Readings can vary throughout the day and can be temporarily influenced by things like emotions, diet and medications. A record of readings regularly taken at home gives a clearer picture of your blood pressure.

Figure 1. Example of health-related passage that was presented to participants. This display was presented on a computer display with black background and white text.

Procedure

Participants were tested individually in a 2-hr session that included breaks as needed. After providing informed consent they completed the demographic questionnaire. Next, they completed the Hypertension Knowledge Questionnaire. In this way, hypertension knowledge was measured before any learning that might result from reading the hypertension passages. Next, participants read the nine passages at their own pace, which were presented one at a time on a computer screen. After reading all nine passages, their memory for the passages was measured by the cued recall test. Finally, participants completed the speed of processing, advanced vocabulary, spatial ability, working memory, and health literacy measures.

Results

We first report a correlational analysis exploring associations between passage recall accuracy and STOFHLA, as well as the other participant variables. A mediation analysis to examine whether the relationship between the STOFHLA and recall could be explained by more general cognitive abilities, focusing on knowledge and processing capacity, is then reported. Finally, regression analysis is used to investigate the relationship between processing capacity and knowledge as predictors of recall of the hypertension-related information.

Following the P-K model, processing capacity, general knowledge, and health knowledge scores were used in the analyses. A processing capacity composite score was created by averaging the standardized scores for Letter Comparison, Pattern Comparison, Card Rotation, Hidden Pattern, and Letter Number Sequencing tests. General knowledge was measured by the standardized Advanced Vocabulary score. Health knowledge was measured by the standardized hypertension knowledge accuracy score.

Association Between Recall and Participant Variables

We investigated relationships among health literacy, age, education, and the ability variables (processing capacity, general and health knowledge), as well as associations of these participant characteristics to passage recall. Although performance on the STOFHLA was high with limited variability, Table 2 shows that this measure was positively associated with processing capacity, general knowledge, and hypertension knowledge as well as education, as predicted by the P-K model. Also consistent with the model, and the cognitive aging literature more generally, age was negatively associated with health literacy and processing

Table 2. Correlations Among Age, Education, Processing Capacity (PC), General Knowledge (GK) and Health Knowledge (HK), Health Literacy (HL), and Recall Performance

	Education	PC	GK	HK	HL	Recall
Age	−.12	−.34*	−.03	−.07	−.28*	−.32*
Education		.38*	.53*	.36*	.32*	.52*
PC			.48*	.27*	.51*	.55*
GK				.41*	.46*	.61*
HK					.20*	.50*
HL						.58*

Note: *$p < .05$.

capacity but did not relate to knowledge. Most important, passage recall was positively associated with health literacy and the broader cognitive abilities. We next analyze these relationships in more detail.

Mediation Analysis of Recall

The P-K model suggests that the impact of health literacy on memory for health information should depend on processing capacity, which constrains comprehension, and knowledge, which supports comprehension. To evaluate this prediction, we examined whether processing capacity, general knowledge, and health knowledge mediated the effects of health literacy (STOFHLA) on passage recall (Preacher & Hayes, 2008; see Figure 2). All the measures were standardized. Controlling for age, results showed significant indirect effects of general knowledge ($B = 0.15$, $SE = 0.05$) and health knowledge ($B = 0.06$, $SE = 0.03$), as well as a moderate indirect effect of processing capacity ($B = 0.06$, $SE = 0.03$). When age was not controlled in the analysis, the indirect effect of processing capacity was strong ($B = 0.10$, $SE = 0.04$). In addition to the total indirect effects of processing capacity, general and health knowledge ($B = 0.27$, $SE = 0.06$), the direct effect of health literacy on recall performance remained significant ($B = 0.24$, $SE = 0.07$, $t = 3.72$, $p < .001$). Therefore, controlling for the three broader abilities attenuated the relationship of health literacy to recall by about 50%, suggesting these abilities mediated effects of health literacy on recall and are important components of health literacy that influence self-care.

Regression Models of Recall Performance

We next explored whether processing capacity and knowledge interacted in order to influence recall of self-care information. Guided by the P-K model, we used multiple regression models to examine the effects of age, processing capacity, and knowledge (both general and health-specific) on recall performance. Education was not included in the model because it was highly correlated with general knowledge ($r = .53$, $p < .001$), posing a potential collinearity problem. Health knowledge was also moderately correlated with general knowledge ($r = .41$, $p < .01$). To address this collinearity problem between these two theoretically important variables, we used the studentized residuals of health knowledge on general knowledge in the regression model. Variables were entered in the following order (see Table 3): (a) age, (b) processing capacity, (c) general knowledge and health knowledge. We also explored possible tradeoffs between knowledge and processing capacity as determinants of memory for self-care information by computing the product of processing capacity and knowledge to create the processing capacity × general knowledge and processing capacity × health knowledge interaction terms. These were entered as the final steps of the regression model, with the main effects of processing capacity, general and health knowledge controlled.

Table 3 shows that age, processing capacity, and general and health knowledge were associated with recall of the health passages. Within this sample of older adults, the participants with higher recall of hypertension-related passages had lower age and more processing capacity, general knowledge, and health knowledge. Most interesting, there was a significant interaction between processing capacity and general knowledge on recall performance. The simple

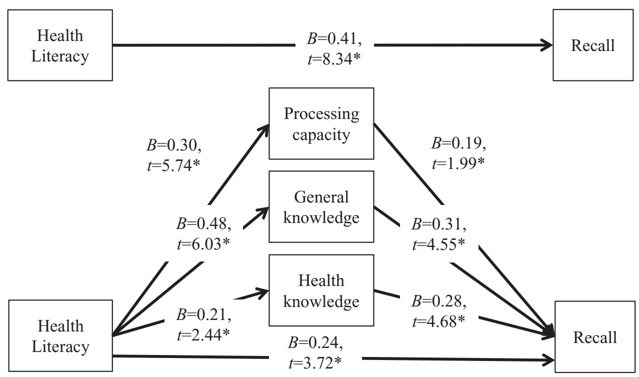

Figure 2. Processing capacity, general knowledge, and health knowledge as the mediators of the association between health literacy and recall (*$p < .05$).

Table 3. Regression Model Examining Correlates of Recall Performance (Standardized Beta Coefficients Are Listed in Each Step)

Variable	Step 1	Step 2	Step 3	Step 4	Step 5
Model R^2	.09*	.30*	.55*	.56*	.57*
Age	−.31*	−.14	−.21*	−.20*	−.21*
PC		.49*	.21*	.22*	.21*
GK			.50*	.50*	.47*
HK			.02*	.27*	.26*
PC × HK				.10	.08
PC × GK					−.15*

Notes: PC = processing capacity; GK = general knowledge; HK = studentized residuals of health knowledge.
*$p < .01$.

slope analysis (Preacher, Curran, & Bauer, 2006) decomposed the interaction term into the simple regression of processing capacity on recall at different levels of general knowledge. Figure 3 shows that although lower levels of processing capacity reduced recall overall, this cost was attenuated for older adults with higher levels of general knowledge (B = 0.14, SE = 0.87; B = 0.09, SE = 0.69; B = 0.04, SE = 0.91 for lower, medium, and higher general knowledge group, respectively).

Discussion

This study examined the relationship between health literacy and recall of information about managing hypertension among older adults. According to the P-K model, health literacy depends on a constellation of basic cognitive abilities and knowledge that influences comprehension of and decisions about health information. Consistent with this model, we found that performance on the STOFHLA measure of health literacy was associated with recall of hypertension information. Moreover, the relationship between health literacy and recall was mediated by measures of processing capacity, general knowledge, and health knowledge, presumably because these abilities also explained performance on the STOFHLA (also see Chin et al., 2011; Levinthal et al., 2008).

The P-K model also suggests that processing capacity and knowledge interact to influence comprehension of self-care information because these abilities have different age-related trajectories. Knowledge, an age-related asset that often is invariant or increases with age, may help offset the influence of processing capacity, which declines with age. Consistent with this prediction, earlier investigations have shown that processing capacity is a positive predictor of performance on standard measures of health literacy among older adults with relatively low levels of knowledge

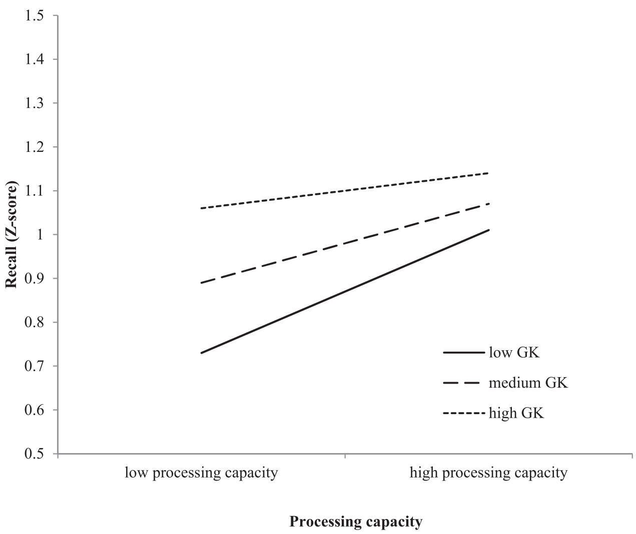

Figure 3. Interaction of processing capacity and general knowledge (GK) on recall of health texts.

but that processing capacity does not predict health literacy performance among those with more knowledge (Chin et al., 2011). In the present study, we extended this finding by showing that general knowledge moderated the effects of processing capacity on the recall of hypertension information: Processing capacity had a greater influence on recall among older adults with lower knowledge. Both studies suggest that knowledge helps to compensate for processing capacity limits in order to support older adults' recall of health information.

Our findings have several implications for understanding the role of health literacy in self-care and for improving health outcomes. First, given that memory for health information has been found to predict adherence and other self-care behaviors (McPherson et al., 2008), our study provides evidence about the mechanisms through which health literacy influences health behaviors and outcomes. The link between health literacy and health behaviors, in part, may be explained by the impact of health literacy on comprehension of and memory for information needed for self-care, which in turn can be partly explained in terms of the effects of processing capacity and knowledge on the efficiency and accuracy of comprehension and memory processes (Kintsch, 1998).

Both domain-general verbal knowledge and domain-specific health knowledge contributed independently to mediating the relationship between health literacy and recall. Numerically, the effects of general knowledge were larger than those of the health knowledge. However, given that the effects of health knowledge were estimated by controlling for the variance it shared with domain-general, we may have underestimated the strength of health knowledge as a mediator. In addition, previous studies suggested that the relationship between knowledge and health literacy might depend on the health literacy measure (Chin et al., 2011). For example, health knowledge has been found to be less related to performance on the STOFHLA relative to other health literacy measures, such as the REALM, perhaps because many questions on the STOFHLA can be answered based on linguistic rather than health-specific knowledge. With the use of STOFHLA in this study, we still found that health knowledge played a role in mediating effects of health literacy on recall showing the importance of health knowledge for understanding health information.

We also found that health literacy still predicted recall of hypertension information even after controlling for the effects of age, processing capacity, and knowledge. This finding suggests that the STOFHLA measure taps other processes that influence recall of health information. For example, the previous literature suggests that patients' beliefs about their illness, or their illness representation, influence their self-care behavior (e.g., Duwe et al., 2014; Leventhal et al., 1983). Although patients' illness representations are partly associated with health knowledge, presumably through experience with the illness (e.g., Chin et al., 2009), our measure of hypertension knowledge may not have adequately measured this construct. Future research should address other factors that may contribute to health literacy and in turn influence the self-care of illness.

A second implication of our results stems from the finding that knowledge helped to compensate for processing capacity constraints on recall of health information. In the current study, we found that general knowledge, but not domain-specific health knowledge, offset the impact of processing capacity on recall of health information. The conservative measurement of health knowledge controlling for verbal ability may have contributed to difficulty in detecting the interaction. In fact, health knowledge has been shown to offset the impact of processing capacity on health literacy, as measured by REALM performance (Chin et al., 2011).

Theoretically, these finding suggests that good health literacy can be achieved in different ways. Patients may rely on knowledge when processing capacity is very limited (e.g., older adults who have chronic illness for many years may rely on illness knowledge despite age-related declines in processing capacity), or they may rely more on processing capacity in the absence of knowledge (e.g., younger adults recently diagnosed with an illness may rely more on domain-general processing capacity than on health knowledge; Chin et al., 2009). More practically, the finding has important implications for improving patient education. If older adults can offset the effects of age-related processing capacity constraints on comprehension by relying on knowledge, it is important to help them learn about their health care by designing learning experiences that make minimal demands on processing capacity. For example, patient education materials can be designed to clearly signal key concepts and how they are signaled (e.g., use of headers), reducing the need for effortful search and reorganization processes. Moreover, older adults are likely to better understand health education materials that build on their knowledge, so that new information can be understood in terms of existing concepts (e.g., familiar words; explaining new concepts in terms of familiar concepts) or health knowledge (e.g., organizing new information to be consistent with patients' expectations). Hence, from the standpoint of health communication (intervention, text design), it *matters* whether a particular patient has low health literacy because of limited processing capacity, knowledge, or both.

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