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Health Literacy and Online Health Information Processing: Unraveling the Underlying Mechanisms

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The usefulness of the Internet as a health information source largely depends on the receiver's health literacy. This study investigates the mechanisms through which health literacy affects information recall and website attitudes. Using 2 independent surveys addressing different Dutch health websites ($N = 423$ and $N = 395$), we tested the mediating role of cognitive load, imagination ease, and website involvement. The results showed that the influence of health literacy on information recall and website attitudes was mediated by cognitive load and imagination ease but only marginally by website involvement. Thus, to improve recall and attitudes among people with lower health literacy, online health communication should consist of information that is not cognitively demanding and that is easy to imagine.

The Internet is a powerful source of information that makes an unlimited amount of information available to everyone. In the United States 84% of adults use the Internet (Perrin & Duggan, 2015), and in The Netherlands 97% of the adult population has Internet access (Statistics Netherlands, 2014). Moreover, more than two thirds of the U.S. adult population currently owns a smartphone (Smith, 2015). Because nearly anything can be found online, this suggests that access to information no longer divides groups in society. Smartphones in particular are expected to decrease the digital divide created by the Internet, as they offer opportunities to reach population groups that were difficult to reach before (Fiordelli, Diviani, & Schulz, 2013). Equal physical access to the Internet, however, does not necessarily correspond to an equal ability to understand and use online information. For some population groups, finding, evaluating, and understanding information is more difficult than it is for others.

Information is a valuable asset in many domains, including health. The extent to which people are able to benefit from online information largely depends on their level of *health literacy*, defined as the “ability to obtain, process, understand, and communicate about health-related information needed to make informed health decisions” (Berkman, Davis, & McCormack, 2010, p. 16). People with lower health literacy are less able to understand and use health information in their daily lives. Lower health literacy is quite prevalent in Western societies (HLS-EU

Consortium, 2012; Kutner, Greenberg, Jin, & Paulsen, 2006). Therefore, despite the similar access to technology (Jensen, King, Davis, & Guntzviller, 2010), lower health literacy might jeopardize the potential of the Internet as a health information source. Research has shown that online health information is often complex and written at a reading level that is difficult to understand (Lachance, Erby, Ford, Allen, & Kaphingst, 2010; McInnes & Haglund, 2011). If people with higher health literacy are able to process and understand online information and people with lower literacy are not, the knowledge gap between these groups will increase.

Although the concept of health literacy keeps evolving and multiple perspectives exist, health information processing is a key element of several health literacy frameworks (Sørensen et al., 2012). However, information processing is often a black box (Geiger & Newhagen, 1993). To design effective strategies for online health information that suit people of all health literacy levels, experts need to know through which pathways health literacy facilitates information processing and, subsequently, message effects. According to Von Wagner, Steptoe, and colleagues (2009), health literacy has both cognitive (e.g., knowledge, understanding) and affective (e.g., attitudes and beliefs) effects. Both are important because they are suggested to be related to health care access and use, patient–provider interactions, self-management, and the ability to make informed decisions (Marteau, Dormandy, & Michie, 2001; Paasche-Orlow & Wolf, 2007). In this study, we investigate the mechanisms underlying the effect of health literacy on cognitive and affective message effects (i.e., information recall and website attitudes). The mediating roles of cognitive load, imagination ease, and involvement with the information are tested. These mechanisms have been suggested in the literature (Meppelink, Smit, Burman, & Van Weert, 2015; Von Wagner, Semmler, Good, & Wardle, 2009; Wilson & Wolf, 2009) but have not, to our knowledge, been tested empirically or in combination. Through this testing, our article responds to the call for theory-driven studies on health literacy and e-health (Mackert, Champlin, Holton, Muñoz,

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& Damásio, 2014) and adds to the body of European health literacy studies, which is currently limited (Barry, D'Eath, & Sixsmith, 2013).

Cognitive Load, Imagination Ease, and Website Involvement

The first mechanism tested is the mediating role of the cognitive load that is required for information processing. According to Lang's (2000) limited capacity model of motivated mediated message processing, full message processing comprises three subprocesses: message encoding, storage, and retrieval. Each subprocess requires cognitive capacity to be completed. However, human cognitive capacity is limited. This means that if reading a message and deriving meaning from its content (information encoding) require much cognitive capacity, there will be less capacity left for message storage and ultimately retrieval. Lower health literacy was found to be associated with greater effort in reading (Von Wagner, Semmler, et al., 2009), which could possibly increase people's risk of experiencing cognitive overload when processing health information (Wilson & Wolf, 2009). For people with higher health literacy, processing health information might require relatively less cognitive capacity (Chin et al., 2011). This difference in relative cognitive load that information processing requires might affect the amount of information people are able to recall (Lang, 2006), which is in line with cognitive load theory (Sweller, Van Merriënboer, & Paas, 1998). In addition to having a positive influence on recall, the cognitive load associated with information processing may also affect people's attitudes toward the information. Research has shown that pictures that are easy to process result in more positive affect (Winkielman & Cacioppo, 2001). The subjective experience of ease associated with processing information, or processing fluency, has been shown to be a general metacognitive cue that positively influences people's evaluations in various domains (Alter & Oppenheimer, 2009). Most studies related to processing fluency, however, have been conducted with relatively simple stimuli such as pictures or words. Nevertheless, the mechanism might also apply to more difficult materials such as health websites. When this is the case, the relative difference in cognitive load required for information processing, caused by health literacy, will influence not only information recall but also attitudes.

The second mechanism is the mediating role of imagination ease. Successful information processing incorporates the creation of mental models connecting new information to existing knowledge (Lang, 2000; Mayer, 2002). Lower health literacy was found to be associated with less health-related background knowledge (Chin et al., 2011), which might undermine the creation of a correct mental model. According to the cognitive theory of multimedia learning, people have separate channels for processing verbal and visual information (Mayer, 2002), and both channels have their own, limited capacity. This theory has been supported by different studies showing that information presented as both text and pictures was better understood and remembered than text-only information (e.g., Bol et al., 2015; Mayer, 2002). However, research indicated that people with lower health literacy could benefit from illustrations added to complex health information, whereas illustrations made no difference for people with higher levels of health literacy (Meppelink, Smit, et al., 2015). Therefore, for people with

higher health literacy, illustrations might not improve information recall because it is easy for them to imagine the information and make the picture mentally. Furthermore, it has been shown that the subjective ease with which symptom information can be imagined influences people's attitudes toward the recommended behavior (Broemer, 2004). Therefore, we expect that online health information will be less well processed, recalled, and evaluated by people with lower health literacy, for whom the creation of a mental model with respect to health information is more difficult.

The third mechanism is the mediating role of involvement with the website. People with lower health literacy search for health information less often than people with higher health literacy (Kutner et al., 2006). This could be explained by the fact that they are less likely to engage with health information, or they experience motivational barriers when confronted with health information (Von Wagner, Steptoe, et al., 2009). Because of a lack of engagement, people with lower health literacy may put less effort into health information processing, reducing the likelihood that the information will be fully processed and remembered (Lang, 2000). In addition to influencing recall, people's involvement with a website is also assumed to induce positive attitudes. When receivers are involved, this is expected to positively influence message elaboration, which subsequently produces more positive attitudes (Liu & Shrum, 2009). Research on the customization of Web portals has shown that website involvement induced by customization positively influences people's attitudes toward the portal (Kalyanaraman & Sundar, 2006). Research has also suggested that website involvement, induced by website interactivity, generates positive attitudes toward the health website (Lustria, 2007). The three potential mechanisms together lead to the following hypotheses:

- Hypothesis 1: Health literacy positively influences recall of online health information. This relationship is mediated by cognitive load, perceived imagination ease, and website involvement.
- Hypothesis 2: Health literacy positively influences people's attitudes toward online health information. This relationship is mediated by cognitive load, perceived imagination ease, and website involvement.

Method

Website Selection

To rigorously test the influence of perceived cognitive load, perceived imagination ease, and website involvement, we independently tested our hypotheses on two different websites using online surveys. The two websites that were used in this study were selected after an extensive procedure. First we used Google AdWords to identify the health-related topics most often searched for in The Netherlands in the search engine Google.nl over the previous 24 months (November 2012–November 2014). An analysis of 850 health-related search terms showed that Ebola was the most often googled topic, probably because of the Ebola epidemic that was going

on in Western Africa in the summer of 2014. As we preferred a topic that was less transient and more representative of general health information, we chose to focus on the second most searched topic, fibromyalgia.

Subsequently, the search term *fibromyalgia* was entered into the search engine Google.nl on a cookie-free computer. Google is often used by people who are looking for health information (Diviani, Van den Putte, Meppelink, & Van Weert, 2016). The websites were selected using the following exclusion criteria: (a) multiple links to the same website; (b) news results; (c) live feeds; (d) advertisements; (e) other search engine-related material, such as definitions; (f) websites on which the information about fibromyalgia was more than five clicks away; (g) webpages targeting health care professionals; and (h) webpages that provided only a list of links to other content providers. These criteria were also applied in other content analyses (McInnes & Haglund, 2011; Tian, Champlin, Mackert, Lazard, & Agrawal, 2014). The first website was the fibromyalgia page of Thuisarts.nl (i.e., “Home doctor”), a website providing information on numerous health topics to a general audience hosted by the Dutch Society of General Practitioners (Nederlands Huisartsen Genootschap). The information on the site is consistent with medical guidelines for general practitioners. The second website was the fibromyalgia page of Gezondheidsplein.nl (i.e., “Health square”), a leading Dutch commercial health website. The content of this website is approved by a medical professional but does not necessarily reflect specific medical guidelines. In the remainder of this article, we refer to the two websites as the “nonprofit” and the “commercial” websites, respectively. The choice of two websites of different natures was functional, with the goal of increasing the generalizability of our results across different types of websites. It must be noted, however, that these are just examples of Dutch health websites and are not meant to be representative of the respective categories (i.e., nonprofit vs. commercial).

Although both websites were about fibromyalgia, some differences were observed. In addition to being different in length (the nonprofit website consisted of 1,267 words and the commercial one of 601 words), the nonprofit one had no images, whereas the commercial one included an image and an animation. Overall, the contents of the websites were comparable, as both discussed problems commonly experienced by fibromyalgia patients, the unknown cause of the disease, the criteria for diagnosis, and tips on how to relieve fibromyalgia pain. The websites differed on some aspects: For example, the commercial website stated that fibromyalgia is a rheumatic disease, whereas the nonprofit one did not. Screenshots of the websites are presented in Figures 1 and 2.

Survey Procedure

The Amsterdam School of Communication Research provided ethical approval for this study (2015-CW-7). Data were collected between February 27 and March 5, 2015. An online survey was e-mailed to the participants and started with questions about gender, age, and education level. Furthermore, health-related Internet use and self-reported knowledge about the topic of the website, fibromyalgia, were assessed. Then respondents visited an existing

Fig. 1. Fibromyalgia page of Thuisarts.nl (nonprofit website).

website about fibromyalgia. People were instructed to imagine that they were searching for information about fibromyalgia online and found this website. After participants visited the website, the survey continued, measuring information recall, attitude toward the website, website involvement, perceived cognitive load, and perceived imagination ease. Health literacy was measured at the end of the questionnaire.

Participants

Data collection was conducted by the research company PanelClix (ISO certified). PanelClix operates in multiple European countries, and the Dutch participant pool consists of more than 100,000 members. The respondents in this study were randomly selected from this large pool. As a reward for their participation, people earned credits (150 Clix), which could be exchanged for cash (€1.50 or more, depending on how many Clix the respondent had earned before). A stratified sample was used, with strata corresponding to the Dutch population in terms of gender, age, and education level. Before the survey was sent to the participants, it was pretested several times for completion time and usability with people who were not part of the final sample.

The screenshot shows the website 'Gezondheidsplein.nl' with a navigation bar at the top. The main content area is titled 'Fibromyalgie' and includes several sections: 'Wat is fibromyalgie?' (What is fibromyalgia?), 'Oorzaken van fibromyalgie' (Causes of fibromyalgia), 'Symptomen van fibromyalgie' (Symptoms of fibromyalgia), and 'Diagnose van fibromyalgie' (Diagnosis of fibromyalgia). There are also sidebars for 'Video van de week' (Video of the week) and 'Specials & Dossiers' (Specials & Dossiers). The page layout is clean and professional, typical of a health information website.

Fig. 2. Fibromyalgia page of Gezondheidsplein.nl (commercial website).

Of the 1,784 people who viewed the first page of the survey, 1,091 (61.15%) were eligible to participate. A total of 693 individuals (38.85%) were excluded because the stratum to which they belonged was already full. Participants were assigned an anonymous Participant Identification Code. Identical Participant Identification Codes in the data set revealed that 13 participants (1.19%) were exposed to the survey twice. In these cases, the second entry was excluded from the analysis. Eighteen cases (1.65%) were excluded because participation took place on a smartphone, although the introduction text clearly mentioned that the questionnaire was not suitable for a smartphone (as the screen would be too small to see the desktop version of the website). Of the 1,002 people who continued after the informed consent page, 821 (81.93%) completed the questionnaire. Finally, three cases were removed because the first respondent reported that he had not seen a website at all, the second one directly copied and pasted the answers from the website, and the third respondent answered all open-ended

questions by writing “not applicable.” As health literacy was measured at the end of the questionnaire, only fully completed questionnaires were used in the analysis.

Measures

Health Literacy

To assess health literacy, we used the comprehension test of the 22-item version of the Short Assessment of Health Literacy in Dutch (SAHL-D; Pander Maat, Essink-Bot, Leenaars, & Fransen, 2014). Participants were exposed to 22 multiple-choice questions for which they had to select the accurate meaning of a health-related word (e.g., *pancreas*, *biopsy*, *psoriasis*). For each correct answer, 1 point was awarded. Incorrect and “I don’t know” answers received no points. SAHL-D scores ranged from 0 to 22 (nonprofit: $M = 15.08$, $SD = 4.84$; commercial: $M = 15.14$, $SD = 4.70$).

Information Recall

Recall of information was measured with 13 open-ended questions, using an adapted version of The Netherlands Patient Information Recall Questionnaire (Jansen et al., 2008). Seven questions were identical for both websites and six were different because of differences in webpage content. Recall questions were pretested for clarity and understandability. A predefined codebook was used to score each answer, with scores of 0 (*false*), 1 (*partly good*), or 2 (*good*). Recall scores ranged from 0 to 26 (nonprofit: $M = 8.50$, $SD = 6.97$; commercial: $M = 9.65$, $SD = 6.44$). In both samples, 15% of the cases ($n = 68$) were coded by a second coder who was not part of the research team. Interrater reliability was good (Cohen’s κ : nonprofit = 0.93, range = 0.70–1.00; commercial = 0.85, range = 0.75–1.00).

Attitude Toward the Website

Attitude toward the site was measured with nine items on a 7-point Likert scale. Items were based on the Website Satisfaction Scale (Bol et al., 2014) and a measure of attitudes toward information (Chang & Thorson, 2004) and included items such as “The website is pleasant,” “The website is appealing,” and “The website is informative.” Answer options ranged from 1 (*totally disagree*) to 7 (*totally agree*). The scale was reliable (nonprofit: $\alpha = .92$, $M = 4.93$, $SD = 0.94$; commercial: $\alpha = .93$, $M = 4.87$, $SD = 1.01$).

Perceived Cognitive Load

Perceived cognitive load was measured with four items on a 7-point Likert scale (Eveland & Dunwoody, 2001; Van Cauwenberge, Schaap, & Van Roy, 2014). Statements included “Sometimes I felt ‘lost’ when reading the website” (reversed) and “The main points of the story were clear and coherent.” Scores ranged from 1 (*much cognitive load*) to 7 (*little cognitive load*). The scale was reliable (nonprofit: $\alpha = .81$, $M = 5.19$, $SD = 1.04$; commercial: $\alpha = .80$, $M = 5.23$, $SD = 1.07$).

Perceived Imagination Ease

Three items were used to measure the ease with which the message could be imagined (Keller & Block, 1997). The semantic differential scales had the following endpoints: The information on the website is *very difficult to imagine* (1), *is very easy to imagine* (7); *is very difficult to picture* (1), *is very easy to picture* (7).

(7); does not appeal to the imagination at all (1), appeals to the imagination very much (7). The scale was reliable (nonprofit: $\alpha = .88$, $M = 5.08$, $SD = 1.14$; commercial: $\alpha = .88$, $M = 5.18$, $SD = 1.05$).

Website Involvement

Website involvement was measured with four items using the Website Involvement Scale (Dutta-Bergman, 2004). Items included, for example, "I tried hard to evaluate the information on the website" and "I was highly involved in evaluating the website." Answer options ranged from *totally disagree* (1) to *totally agree* (7). For the commercial website, the involvement measure was extended with two items that addressed involvement with the pictures and animations on the website, which were absent from the nonprofit one. The scale was reliable (nonprofit: $\alpha = .81$, $M = 4.50$, $SD = 1.03$; commercial: $\alpha = .84$, $M = 4.56$, $SD = 1.07$).

Control Variables

In addition to gender and age, we measured several variables to control for their potential influence. The variable education level consisted of nine response categories that were coded into three categorical variables identifying respondents with a low (primary, lower vocational, preparatory secondary vocational, and intermediate secondary vocational education), middle (senior secondary vocational and university preparatory vocational education), and high (higher vocational education and university) level of education. Furthermore, we asked the respondents how often they used the Internet for health information, whether they were medical professionals, how much they knew about fibromyalgia, whether they had fibromyalgia themselves, whether they had previously searched for information about fibromyalgia online, and whether they had visited the specific webpage before.

Statistical Analysis

First, all variables were checked for normality before they were used in the analyses (skewness between -1 and 1 , kurtosis between -3 and 3). Subsequently, we ran a correlational analysis using SPSS 22 to examine the relationships among the variables. Correlation matrices for both samples are presented in Tables 1 and 2. Subsequently, we used PROCESS (Model 4, 10,000 bootstrapped samples) to test our hypotheses. PROCESS is a macro for SPSS that estimates 95% bias-corrected confidence intervals (CIs) for total and specific indirect effects by means of bootstrapping. Model 4 in PROCESS allows for the testing of multiple mediators in parallel to examine different mechanisms against each other (Hayes, 2013). PROCESS specifies specific indirect effects for each mediator while keeping the other mediators constant. Significant effects are indicated by 95% CIs that do not include 0. Two mediation models were tested, with information recall and website attitudes as dependent variables. Health literacy was the independent variable in both models.

Results

Table 3 provides an overview of both samples. The groups were comparable in terms of gender, age, and education level. Respondents were also representative of the Dutch population based on the strata used by the research company. Most people

consulted the Internet for health purposes a few times per year, although almost 10% of the individuals used the Internet a few times per week to find health information. In both samples, 14% of the people were medical professionals, and 25% had previously searched for information about fibromyalgia online.

Survey 1: Nonprofit (Thuisarts.nl)

To test our first hypothesis, we used health literacy as the independent variable; recall as the dependent variable; and cognitive load, imagination ease, and website involvement as three parallel mediators.¹ The results showed a significant indirect relationship between health literacy and information recall through cognitive load ($b = 0.18$, 95% CI [0.11, 0.27]). Imagination ease ($b = 0.03$, 95% CI [-0.03, 0.10]) and involvement ($b = 0.01$, 95% CI [-0.00, 0.04]) did not mediate the relationship. In addition to the indirect effects, health literacy was also directly associated with recall ($b = 0.46$, 95% CI [0.33, 0.59]). To eliminate the influence of prior knowledge on the mediators as well as recall, we included self-reported knowledge about fibromyalgia as a control variable in the analysis and therefore kept it constant.² The direct and indirect paths are presented in Figure 3.

Similarly, we tested the indirect relationship between health literacy and attitude toward the website through cognitive load, imagination ease, and website involvement. To be consistent, we included self-reported knowledge about fibromyalgia as a control variable.³ We found a significant indirect relationship between health literacy and attitudes toward the site through cognitive load ($b = 0.02$, 95% CI [0.01, 0.03]) as well as through imagination ease ($b = 0.02$, 95% CI [0.01, 0.03]). No indirect relation was found through involvement ($b = 0.01$, 95% CI [-0.00, 0.01]). There was no significant difference in effect size between cognitive load and imagination ease, meaning that both mediators explained the relationship between health literacy and website attitudes to an equal extent. In addition, health literacy was not associated with website attitude directly ($b = -0.01$, 95% CI [-0.03, 0.00]). The direct and indirect relationships are presented in Figure 4.

¹Although the website automatically closed when people continued with the questionnaire, 43 respondents reported that they had consulted the website a second time when they answered the recall questions. This was possible, as we used a real website. Because we aimed to measure recall of information and not the ability to find information, these people were excluded from the model in which recall was the dependent variable.

²We also tested the model with other variables that are associated with the dependent variable recall and at least one of the mediators (i.e., gender, education level, and having previously visited the website). When we included each of these variables as a control variable, this did not change the outcomes.

³We also tested the model with other variables that are associated with the dependent variable attitudes and at least one of the mediators (i.e., age, frequency of online health information seeking, online information seeking for fibromyalgia, and having previously visited the website). When we included each of these variables as a control variable, this did not change the outcomes.

Table 1. Correlation Matrix Survey 1, nonprofit ($N = 423$)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Gender (1 = female)	—														
2. Age	-.06	—													
3. Education	-.01	-.15**	—												
4. Health literacy	.25***	.21***	.25***	—											
5. Recall	.20***	.05	.20***	.49***	—										
6. Attitude toward website	-.04	.13**	.01	.16**	.21***	—									
7. Involvement	.09	.15**	.01	.13**	.22***	.41***	—								
8. Cognitive load	.04	.12*	.12*	.41***	.51***	.44***	.28***	—							
9. Imagination ease	-.03	.16**	.09	.35***	.39***	.45***	.26***	.58***	—						
10. Self-reported knowledge about fibromyalgia	.16**	-.06	.10*	.21***	.11*	.07	.22***	.09	.05	—					
11. Online health information seeking	.12*	-.04	.10*	.13**	.02	.12*	.20***	.06	.07	.30**	—				
12. Fibromyalgia patient (1 = yes)	.06	.07	-.02	.08	.07	-.01	.01	-.03	.04	.29***	.06	—			
13. Online information seeking for fibromyalgia (1 = yes)	.06	.04	.09	.16**	.09	.12*	.19***	.13**	.11*	.63***	.21***	.28***	—		
14. Previously visited the website (1 = yes)	.03	-.16**	-.01	-.03	.11*	.14**	.16**	.16**	.11*	.18***	.19***	.07	.23***	—	
15. Medical professional (1 = yes)	.23***	-.13**	.13**	.16**	.04	.05	.13**	-.01	.04	.40***	.11*	.04	.28***	.071	—

* $p < .05$. ** $p < .01$. *** $p < .001$.

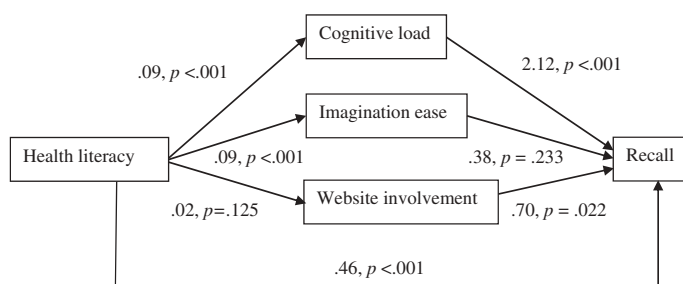
Table 2. Correlation Matrix Survey 2, commercial (N = 395)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Gender (1 = female)	—														
2. Age	-.02	—													
3. Education	.00	-.09	—												
4. Health literacy	.21***	.22***	.31***	—											
5. Recall	.19***	.03	.11*	.44***	—										
6. Attitude toward the website	.02	.11*	.11*	.13**	.22***	—									
7. Website involvement	.07	.08	.08	.14**	.26***	.47***	—								
8. Cognitive load	.12*	.14**	.09	.38***	.42***	.35***	.30***	—							
9. Imagination ease	.13*	.12*	.14**	.35***	.38***	.38***	.34***	.62***	—						
10. Self-reported knowledge about fibromyalgia	.21***	-.01	.12*	.18***	.08	.16**	.21***	.04	.20***	—					
11. Online health information seeking	.11*	-.08	.07	.12*	.00	.10*	.22**	.04	.06	.30***	—				
12. Fibromyalgia patient (1 = yes)	.16**	.13*	-.08	.04	.08	.05	.16**	.07	.19***	.43***	.13*	—			
13. Online information seeking for fibromyalgia (1 = yes)	.15**	.10	.07	.16**	.08	.12*	.14**	.07	.18***	.55***	.21***	.35***	—		
14. Previously visited the website (1 = yes)	.15**	-.12*	.05	.07	.09	.16**	.14**	.14**	.14**	.23***	.19***	.20***	.27***	—	
15. Medical professional (1 = yes)	.15**	-.14**	.03	.05	-.01	.01	-.02	.02	.02	.24***	.21***	.06	.17**	.10	—

*p < .05. **p < .01. ***p < .001.

Table 3. Participant characteristics

Variable	Survey 1, nonprofit (<i>N</i> = 423)		Survey 2, commercial (<i>N</i> = 395)	
	<i>n</i>	%	<i>n</i>	%
Gender				
Male	221	52.2	203	51.4
Female	202	47.8	192	48.6
Age (years)				
<i>M</i> (<i>SD</i>)	45.11 (16.07)		45.12 (15.8)	
Range	18–78		18–75	
Education level				
Low	99	23.4	94	23.8
Middle	213	50.4	187	47.3
High	111	26.2	114	28.9
Internet use for health purposes				
Never	18	4.3	16	4.1
Once per year	22	5.2	31	7.8
Few times per year	130	30.7	111	28.1
Once per month	84	19.9	78	19.7
Few times per month	92	21.7	75	19.0
Once per week	41	9.7	46	11.6
Few times per week	36	8.5	38	9.6
Professional medical background				
Yes	61	14.4	57	14.4
No	362	85.6	338	85.6
Perceived knowledge of fibromyalgia (range = 1–7), <i>M</i> (<i>SD</i>)	2.66 (1.72)		2.71 (1.70)	
Fibromyalgia patient				
Yes	37	8.7	45	11.4
No	386	91.3	350	88.6
Previously searched for information about fibromyalgia online				
Yes	106	25.1	103	26.1
No	317	74.9	292	73.9
Previously visited the specific website				
Yes	76	18.0	99	25.1
No	347	82.0	296	74.9

**Fig. 3.** Relationship between health literacy and recall for the nonprofit website. *N* = 380. Unstandardized coefficients are reported. In the model, self-reported knowledge of fibromyalgia is kept constant.**Survey 2: Commercial (Gezondheidsplein.nl)**

The same analyses were performed with a different sample of participants who had been exposed to a different website: the fibromyalgia page of Gezondheidsplein.nl. First, the indirect association between health literacy and information recall was tested through

cognitive load, imagination ease, and website involvement. To be consistent with the analyses conducted for the nonprofit website, we added self-reported knowledge of fibromyalgia as a control variable and kept it constant in the analysis to prevent it from influencing recall of information.⁴ For the commercial website, health literacy was associated with information recall not only through cognitive load ($b = 0.11$, 95% CI [0.05, 0.19]) but also through imagination ease ($b = 0.07$, 95% CI [0.01, 0.14]) and involvement ($b = 0.02$, 95% CI [0.00, 0.05]). Although all mediators were found to play a role in explaining the relationship between health literacy and information recall, the effect of involvement was significantly smaller than the effect of cognitive load ($b = -0.09$, 95% CI [-0.18, -0.02]). No other differences in effect sizes were observed between the three mediators. Furthermore, health literacy was also directly related to recall ($b = 0.39$, 95% CI [0.26, 0.52]). The direct and indirect relations are presented in Figure 5.

⁴We also tested the model with other variables that are associated with the dependent variable recall and at least one of the mediators (i.e., gender and education level). When we included each of these variables as a control variable, this did not change the outcomes.

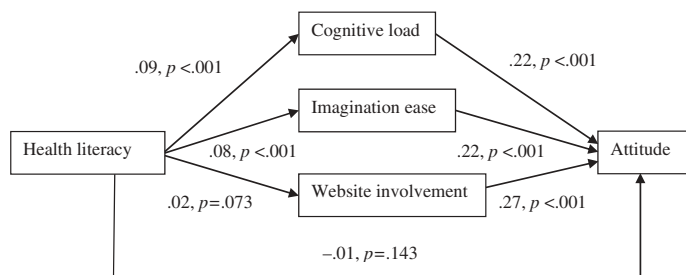


Fig. 4. Relationship between health literacy and attitude for the nonprofit website. $N = 423$. Unstandardized coefficients are reported. In the model, self-reported knowledge of fibromyalgia is kept constant.

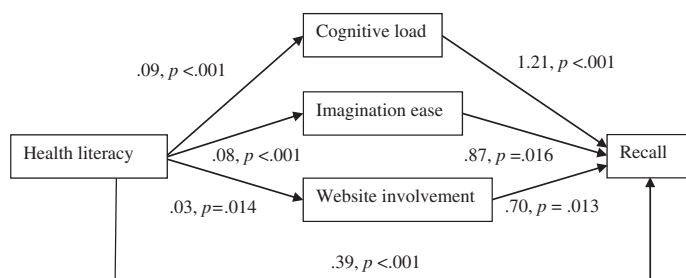


Fig. 5. Relationship between health literacy and recall for the commercial website. $N = 367$. Unstandardized coefficients are reported. In the model, self-reported knowledge of fibromyalgia is kept constant.

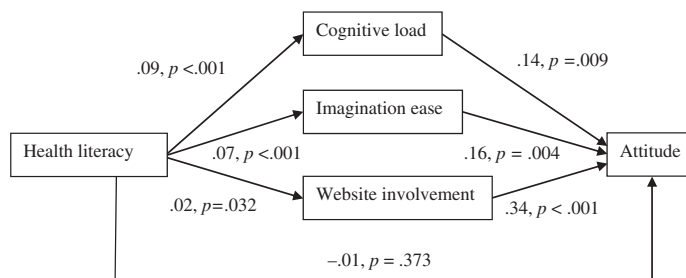


Fig. 6. Relationship between health literacy and attitude for the commercial website. $N = 395$. Unstandardized coefficients are reported. In the model, self-reported knowledge of fibromyalgia is kept constant.

Last, we tested the hypothesis in which attitude toward the website was the dependent variable for the commercial website. Self-reported knowledge of fibromyalgia was again added as a control variable to the analysis.⁵ Health literacy was indirectly associated with attitude toward the website through cognitive load ($b = 0.01$, 95% CI [0.00,

0.02]), imagination ease ($b = 0.01$, 95% CI [0.00, 0.02]), as well as website involvement ($b = 0.01$, 95% CI [0.00, 0.02]). The mediators did not differ significantly in terms of effect size, and health literacy did not relate directly to people's attitude toward the website ($b = -0.01$, 95% CI [-0.03, 0.11]). The direct and indirect relationships are presented in Figure 6, and Table 4 provides an overview of all indirect effects.

Discussion

This study investigated the pathways through which health literacy influences recall of and attitude toward online health information by testing three potential underlying mechanisms. The results showed that the relationship between health literacy and information recall was partly mediated by the relative cognitive capacity that is demanded during message processing. People with higher levels of health literacy need less cognitive capacity to process health information, positively influencing information recall. For people with lower health literacy, however, processing the same online information requires more cognitive capacity, resulting in less recall of information. This mechanism was found for both of the websites tested in the study. The underlying role of cognitive load has been suggested by multiple scholars (Von Wagner, Steptoe, et al., 2009; Wilson & Wolf, 2009), but to our knowledge this is the first time that its influence has been empirically tested. Our finding supports the applicability of the limited capacity model of motivated mediated message processing (Lang, 2006) and cognitive load theory (Sweller et al., 1998) to the domain of health literacy and information processing. In addition to information recall, a mediating role of cognitive load with respect to attitudes toward the website was also found in both samples. Thus, the relative ease with which health information can be processed positively influences people's evaluation of this information, supporting the concept of processing fluency (Alter & Oppenheimer, 2009).

In addition, perceived imagination ease appeared to explain the relationship between health literacy and information recall, but only for one website (the commercial website). It is likely that this inconsistency across websites can be explained by the different design characteristics of the sites. Our aim was to test our hypotheses on different types of websites, and we therefore selected two websites that were different in terms of design features. The commercial website incorporated images and an animation about fibromyalgia, whereas the nonprofit one did not present any illustrational material to clarify the text. Moreover, the text on the nonprofit website was substantially longer than the text on the commercial website. These design characteristics might have influenced the ease with which people were able to imagine the information, irrespective of their level of health literacy. However, imagination ease influenced the relationship between health literacy and website attitudes as well, and this result was found for both websites. Thus, for people with higher health literacy, it is easier to imagine the content of a health website, which subsequently positively influences attitudes toward the site.

The final mechanism that was tested was the mediating role of involvement with information on the website. For this mediator we found the least evidence. For the nonprofit website,

⁵We also tested the model with other variables that are associated with the dependent variable attitudes and at least of the mediators (i.e., age, education level, online health information seeking, online information seeking for fibromyalgia, and having previously visited the website). When we included each of these variables as a control variable, this did not change the outcomes.

Table 4. Specific indirect effects for both health websites

Dependent variable and mediator	Survey 1, nonprofit		Survey 2, commercial	
	<i>b</i>	95% CI	<i>b</i>	95% CI
Recall				
Cognitive load	0.18	[0.11, 0.27]	0.11	[0.05, 0.19]
Imagination ease	0.03	[-0.03, 0.10]	0.07	[0.01, 0.14]
Website involvement	0.01	[-0.00, 0.04]	0.02	[0.00, 0.05]
Attitude				
Cognitive load	0.02	[0.01, 0.03]	0.01	[0.00, 0.02]
Imagination ease	0.02	[0.01, 0.03]	0.01	[0.00, 0.02]
Website involvement	0.01	[-0.00, 0.01]	0.01	[0.00, 0.07]

Note. Unstandardized coefficients (*b*) are reported. CI = confidence interval.

involvement did not explain the influence of health literacy on recall or on attitudes toward the website. For the commercial website, significant indirect effects through involvement were found for both outcomes, but these effects were very small. The association between health literacy and website involvement especially was limited, although involvement did positively influence attitudes. This result is encouraging, as it indicates that people with lower health literacy are just as engaged with health information as people with higher health literacy. However, different explanations may apply to this result. Respondents in this study were explicitly asked to pay close attention to the website and its text. Therefore, the level of website involvement of our respondents might have been different from involvement levels in a more natural setting. For example, when people read information on websites, they are more likely to skip information compared to readers of print materials (Lustria, 2007). Furthermore, the scales we used were all self-reports. It is possible that people overestimated their personal involvement level, which might also have impacted our findings. Future research should examine to what extent people with different health literacy levels are involved with health websites when voluntarily searching for health information in a natural setting.

This study has some limitations. It must be noted that the design of our study was cross-sectional. Therefore, our results cannot be interpreted as cause and effect. Longitudinal studies are needed to provide insight into the causality between the variables in this study. Furthermore, the indirect effects that were found in our study were relatively small, especially for website attitudes. This means that variables other than health literacy influence people's attitudes toward health information as well.

As it was our aim to investigate how information processing works for real online websites, we purposely used existing websites in our study. Consequently, we did not control the content of the websites or the design characteristics. As the quality of information processing is influenced by both the receiver and the message, message characteristics might have impacted our findings. However, the fact that most findings were consistent over the two real but completely different websites strongly contributes to the external validity of our study. It must also be noted that we only tested one health condition,

fibromyalgia. It is unclear whether the mechanisms that were found in this study also apply to information about other health conditions. Nevertheless, fibromyalgia is a health condition that is often searched for in The Netherlands and therefore representative of a significant amount of health-related Internet use.

Furthermore, we used the SAHL-D to assess health literacy. As health literacy is a very broad construct that is still evolving (Berkman et al., 2010), there are a wide variety of measures available to assess it (Sørensen et al., 2012). The SAHL-D captures only a limited part of the spectrum, measuring the ability to process and understand health information without considering the ability to obtain and use this information. Nevertheless, we are confident that the SAHL-D was the best measure to be used in this study. The focus on information processing, and the fact that this measure is validated and not a self-report, made the SAHL-D the best option to choose. Future research should address other aspects of health literacy in online contexts, such as people's ability to obtain, evaluate, and use this information. Especially online, where plentiful information is available, skills to find information and to evaluate its reliability are essential (Diviani, Van Den Putte, Giani, & Van Weert, 2015). It would therefore be useful to investigate how people with limited health literacy obtain and evaluate online materials and how these skills can be improved.

Finally, the participants in our study belonged to an online panel, meaning that they were probably used to completing questionnaires. Therefore, it is unlikely that there were many people in our sample with a lack of reading skills. Nevertheless, both samples were representative of the Dutch population (over the age of 18), and the mean health literacy scores did not deviate substantially from those in other studies conducted with this measure in The Netherlands (e.g., Meppelink, Smit, et al., 2015; Pander Maat et al., 2014).

Our study has important implications for health communication practitioners. To improve information processing among people with lower health literacy, the cognitive demands of health messages should be reduced, for example by using non-complex texts (Meppelink, Smit, et al., 2015; Wilson & Wolf, 2009). Furthermore, this study emphasizes the importance of health messages that are easy to imagine, which might especially support people who might have difficulties with creating mental

pictures themselves because of a lack of health-related knowledge. This could be done, for example, by using images, animations, or concrete language (Mayer, 2002; Meppelink, Van Weert, Haven, & Smit, 2015). The finding that involvement only marginally explained the relationships among health literacy, recall, and attitudes is promising, as it suggests that people with lower health literacy do not experience a lack of engagement with information when it comes to health information processing. Therefore, it would be useful to create messages that are easy to process and imagine, but it is not necessary to create different messages in order to engage this population.

Conclusion

To our knowledge, this study is the first to empirically test the mechanisms by which health literacy influences recall of health information and attitudes toward online health information. We found that cognitive load in particular plays a significant role in both recall as well as attitude formation. Imagination ease explained the influence of health literacy on attitudes. For everyone in Western societies to benefit from the Internet as a health information source, health communicators should be aware of these mechanisms and create health messages that are easy to process and appeal to the imagination. When this is done, it might be possible to decrease the health literacy gap with respect to health information processing and ultimately decrease inequalities in society with respect to the usefulness of online health information in people's daily lives.

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