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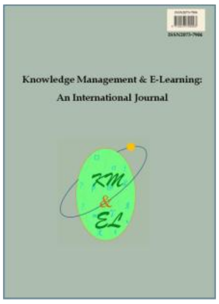

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eHealth literacy demands and cognitive processes underlying barriers in consumer health information seeking

Connie V. Chan
Columbia University, New York, USA
Jelena Mirkovic
Oslo University Hospital, Norway
Stephanie Furniss
David R. Kaufman
Arizona State University, Tempe, AZ, USA

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eHealth literacy demands and cognitive processes underlying barriers in consumer health information seeking

Connie V. Chan

Department of Biomedical Informatics
Columbia University, New York, USA
E-mail: connie.chan@dbmi.columbia.edu

Jelena Mirkovic

Center for Shared Decision Making and Collaborative Care Research
Division of Medicine
Oslo University Hospital, Norway
E-mail: Jelena.Mirkovic@rr-research.no

Stephanie Furniss

Department of Biomedical Informatics
Arizona State University, Tempe, AZ, USA
E-mail: stephanie.furniss@asu.edu

David R. Kaufman*

Department of Biomedical Informatics
Arizona State University, Tempe, AZ, USA
E-mail: dave.kaufman@asu.edu

*Corresponding author

Abstract: *Background*: Consumer eHealth tools play an increasingly important role in engaging patients as participants in managing their health and seeking health information. However, there is a documented gap between the skill and knowledge demands of eHealth systems and user competencies to benefit from these tools. *Objective*: This research aims to reveal the knowledge- and skill-related barriers to effective use of eHealth tools. *Methods*: We used a micro-analytic framework for characterizing the different cognitive dimensions of eHealth literacy to classify task demands and barriers that 20 participants experienced while performing online information-seeking and decision-making tasks. *Results*: Participants ranged widely in their task performance across all 6 tasks as measured by task scores and types of barriers encountered. The highest performing participant experienced only 14 barriers whereas the lowest scoring one experienced 153. A more detailed analysis of two tasks revealed that the highest number of incorrect answers and experienced barriers were caused by tasks requiring: (a) Media literacy and Science literacy at high cognitive complexity levels and (b) a combination of Numeracy and Information literacy at different cognitive complexity levels. *Conclusions*: Applying this type of analysis enabled us to characterize task demands by literacy type and by cognitive complexity. Mapping barriers to literacy types provided insight into the interaction between users and eHealth tasks. Although the gap between eHealth tools, users' skills, and knowledge can be difficult to bridge, an understanding of the cognitive complexity and literacy demands can serve to reduce the gap between designer and consumer.

Keywords: eHealth; Cognition; Consumer health; Information seeking; Task analysis

Biographical notes: Connie V. Chan completed her doctorate in biomedical informatics at Columbia University, with special focus on public health informatics. She has research interests in consumer health informatics, and specifically how consumers understand and use online and mobile resources to interact with the healthcare system and to manage their health.

Jelena Mirkovic is a Research Scientist at the Center For Shared Decision Making and Collaborative Care Research, Oslo University Hospital, Norway. Her research interests are consumer health informatics, with special focus on mHealth systems, usability, user-friendliness and user motivation and engagement.

Stephanie Furniss is a senior doctoral student in the department of Biomedical Informatics at Arizona State University. Her research interests include clinical workflow, the coordination of patient care and situation awareness in medical decision making.

David R. Kaufman is an Associate Professor in the department of Biomedical Informatics at Arizona State University. His research interests include human-computer interaction, human factors with a focus on clinical workflow, eHealth literacy and numeracy.

1. Introduction

Consumer eHealth refers to "health services and information delivered or enhanced through the Internet and related technologies" (Eysenbach, 2001). eHealth tools are rapidly being developed to engage people in managing their own health care, to facilitate communication with providers and social networks, meeting their informational needs, making knowledgeable health decisions, using patient education resources, and promoting healthy lifestyles (Kreps & Neuhauser, 2010; Pagliari, 2007). Some examples of consumer-oriented eHealth tools include: patient health records, health information portals, telemedicine, online support or chat groups, interactive behavior change tools, decision support tools, and chronic disease management systems (Atkinson & Gold, 2002; Eysenbach, 2000). Prior research has described the potential benefits from the effective use of eHealth tools, but studies have also documented a range of barriers that preclude health consumers from fully engaging in and benefiting from eHealth interventions (Jimison et al., 2008). Barriers such as limited literacy, health literacy, and technological familiarity significantly impede consumers' ability to navigate and negotiate eHealth applications (Jensen, King, Davis, & Guntzviller, 2010; Neter & Brainin, 2012). The concept or construct of eHealth literacy refers to a set of skills and knowledge that are essential for productive interactions with technology-based health tools (Norman & Skinner, 2006b).

eHealth literacy-related knowledge and skills are particularly lacking among vulnerable populations (Connolly & Crosby, 2014) (e.g. the elderly (Sharit, Hernández, Czaja, & Pirolli, 2008), disadvantage youth (Subramaniam et al., 2015), or people with lower levels of education (Knapp, Madden, Wang, Sloyer, & Shenkman, 2011)). One way in which consumers may minimize risks is by critically evaluating sources of information and not divulging any private or sensitive information. However, despite having such knowledge, consumers do not always practice these skills or exercise sound judgment (Czaja et al., 2006; Subramaniam et al., 2015). The combination of access, resources, knowledge and skill barriers interact with one another to create obstacles to effective use of eHealth. This is of concern because, according to Eysenbach's "inverse information law", access to information is often most difficult for those who need it most (Eysenbach, 2007).

Searching for health information online is perhaps the most common eHealth activity (Powell, Inglis, Ronnie, & Large, 2011; Rees & Bath, 2001). The process involves a set of information seeking behaviours to meet an information need: identify and articulate an information need, extract the appropriate concepts to formulate a query, evaluate relevance of retrieved results and adapt search directions accordingly (Xiao, Sharman, Rao, & Upadhyaya, 2014). Each stage of the process draws on different cognitive functions, knowledge, and strategies. There are a range of resources available that provide health information yet consumers are increasingly turning to the Internet to meet their health information needs. The Pew Internet Project's survey from September 2012 found that 81% of U.S. adults used the Internet, and, of those, 72% had looked online for health information in the past year (Fox & Duggan, 2013). As a starting point for their health-related searches most online health seekers use a search engine (Google, Bing or Yahoo), while just a smaller percentage use other sources such as specialized health information web sites like WebMD (13%), more general sites like Wikipedia (2%), and social networks (1%) (Fox & Duggan, 2013).

The growing popularity and use of mobile technology has opened possibilities for new ways to address and circumvent existing barriers to the access and use of eHealth tools and information. Pew Internet Project reported that, in 2015, 62% of smartphone owners have used their phone to search for information related to a health condition (Smith, 2015). However, limitations of mobile devices (e.g. small screen, limited input capabilities) have introduced new challenges for designing useful systems for users varying in ehealth literacy (Mirkovic, Kaufman, & Ruland, 2014).

Norman and Skinner introduced a model of eHealth literacy, comprised of multiple literacy types (Norman & Skinner, 2006a; 2006b). These literacies highlighted the fundamental skills consumers require to derive benefits from eHealth. They used the model to develop eHEALS, an 8-item self-report tool to measure "consumers' combined knowledge, comfort, and perceived skills at finding, evaluating, and applying electronic health information to health problems" (Norman & Skinner, 2006a). This is in keeping with the research and practice in health literacy which has led to the development of a range of self-report assessment tools including the Test of Functional Health Literacy (TOFHLA) (Baker, Williams, Parker, Gazmararian, & Nurss, 1999) and the Rapid Estimate of Adult Literacy in Medicine (REALM) (Murphy, Davis, Long, Jackson, & Decker, 1993). Both the TOFHLA and REALM serve as immensely useful screening tools. eHEALS has similarly proved to be useful as an instrument for identifying consumers and patients who may or may not benefit from an eHealth intervention or knowledge resource (Norman, 2011).

In a recent paper, Kayser, Kushniruk, Osborne, Norgaard, and Turner (2015) present a novel eHealth literacy framework for understanding users' needs. The approach leverages the user-task-context matrix developed by Kushniruk and Turner (2012) to differentiate between types of users, their context of use and how these factors interact with usability and safe use of these systems. Kayser et al. (2015) extended this model to include knowledge about users' competences within the various domains of eHealth literacy. The paper presents a multifaceted approach leading to the development of a new eHealth literacy instrument in the form of a comprehensive eHealth questionnaire. A primary goal is to inform the design processes in order to enhance the understanding of users' needs amongst designers of eHealth systems and applications (Kayser et al., 2015).

In a previous paper, we introduced a micro-analytic framework and set of methods for characterizing the different cognitive dimensions of eHealth literacy (Chan & Kaufman, 2011). The Chan-Kaufman analytic framework can be used to classify task demands as well as the barriers encountered in users' task performance. In prior work, we applied the framework analysis to three information seeking tasks for participants using two different health-related websites (MedlinePlus.gov and Medicare.gov) across different health topics (Chan, Matthews, & Kaufman, 2009). The analysis provided task descriptions that summarized the skills and knowledge that participants needed most often to perform each task. The Chan-Kaufman framework differs from eHEALS in that our goals are to develop a diagnostic approach rather than a screening tool. The objective is to identify and diagnose barriers, and like Kayser and colleagues (Kayser et al., 2015), contribute to the solution space that could inform designers, developers and consumer health educators. As described in the framework section below, we employ a cognitive task analytic approach which focuses on the domain, task and application coupled with a method for characterizing the performance of users on a range of eHealth tasks to understand the core skills and knowledge needed to productively use eHealth tools.

In this paper, we apply the Chan-Kaufman analytic approach to reveal challenges experienced by health consumers in performing information-seeking tasks. Specifically, our objective is to characterize the knowledge and skill-related barriers in online consumer health information seeking activity, and reveal eHealth literacy and cognitive dimensions underlying the barriers.

2. Theoretical and methodological framework

The Chan-Kaufman framework draws on the eHealth Literacy Model and Bloom's Taxonomy of the Cognitive Domain.

2.1. eHealth literacy model

eHealth literacy is defined as "the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem" (Norman & Skinner, 2006b). We adapt the eHealth Literacy Model proposed by Norman and Skinner which describes six components of eHealth literacy (Norman & Skinner, 2006b):

- *Computer Literacy* describes the skills to use computers to solve problems, ranging from basic knowledge such as how to open a browser window to developing computer applications.

- *Information Literacy* encompasses the skills to articulate information needs, to locate, evaluate, and use information, and to apply information to create and communicate knowledge (Catts & Lau, 2008).
- *Media Literacy* is the ability to select, interpret, evaluate, contextualize, and create meaning from resources presented in a variety of visual or audio forms (Thoman, 1999). This also includes the ability to assess privacy and security of different resources.
- *Traditional Literacy and Numeracy* encompasses three sub-components: 1) Reading and understanding written passages, 2) Writing, which includes effective written and verbal communication of ideas, and 3) Numeracy, which describes quantitative skills and the ability to interpret information artifacts such as graphs, scales, and forms (Ancker & Kaufman, 2007; Rudd, Moeykens, & Colton, 2000).
- *Science Literacy* includes familiarity with basic biological concepts and the scientific method as well as the ability to understand, evaluate, and interpret health research findings using appropriate scientific reasoning (Laugksch, 2000).
- *Health Literacy* is the acquisition, evaluation, and appropriate application of relevant health information that allows consumers to communicate about health, make health decisions, and utilize health services (McCray, 2005; Rudd, Kirsch, & Yamamoto, 2004).

These six facets of eHealth literacy operate in combination when working on eHealth tasks. They constitute the set of core skills and knowledge.

2.2. Levels of cognitive complexity

The six eHealth literacies describe the skills and knowledge related to eHealth tasks, but cannot explain variation in task performance. Bloom's Taxonomy of the Cognitive Domain is a well-known taxonomy developed to classify levels of intellectual behaviour in learning (Krathwohl, 2002). It was developed in 1956 and updated in 2001; it has been widely applied to develop educational objectives and curriculum, to assess learning, and to create test items. The taxonomy describes a hierarchy of six cognitive processes that increase in complexity and cut across factual, conceptual, procedural, and meta-cognitive knowledge. These six dimensions, listed in order of increasing complexity, are defined as (Amer, 2006):

- *Remembering* is retrieving, recognizing, and recalling relevant knowledge from long-term memory.
- *Understanding* includes constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
- *Applying* involves using knowledge to execute a procedure.
- *Analysing* comprises breaking material into constituent parts, and determining how the parts relate to one another and to the overall structure or purpose through differentiating, organizing, and attributing.
- *Evaluating* involves making judgments based on criteria and standards.

- *Creating* consists of putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

The Chan-Kaufman analytic framework proved useful for describing eHealth tasks across health domains and across health technology applications. It also enabled a deeper exploration of the complex relationships and interactions of the different types of literacy and levels of cognitive complexity. In this paper, we apply the framework to determine whether it can be used to diagnose and characterize information-seeking problems of varying complexity.

3. Methods

3.1. Methods of analysis

We applied the Chan-Kaufman analytic framework in a form of a matrix with the eHealth literacy types along one axis and the six levels of cognitive complexity along the other axis. This matrix of eHealth literacy and complexity definitions constitute the codebook, providing the foundation for analysis. The analysis comprised of three components: 1) a cognitive task analysis, performed by analysts, revealing a task's demands; 2) cognitive studies of participant task performance; and 3) data analysis identifying barriers encountered by participants during task performance.

3.2. Cognitive task analysis

To characterize eHealth literacy demands, we employed a cognitive task analysis (CTA), a cognitive engineering method that decomposes a task to uncover knowledge, goal structures, thought processes, and strategies underlying task completion (Patel, Arocha, & Kaufman, 2001; Roth, Patterson, & Mumaw, 2002). Expert analysts (CC and DK) carried out CTA by performing each task individually, eliciting both information-processing demands of a task and the kinds of domain-specific knowledge required (Patel & Kaufman, 2006). The expert analysts enumerated the actions (either behavioural or cognitive) and knowledge steps used to complete the specified task. Then, the framework was used to code the corresponding types of eHealth literacy and cognitive complexity levels that describe the knowledge and skill level needed to complete each step. For example, a step may require reading a text passage in order to follow the directions in the passage. We first identified and coded that this step requires reading literacy at the Applying level of complexity to use the information in the passage appropriately. The step would also require information literacy at the Understanding level of complexity to be able to meet the appropriate information need while reading the passage. Many steps required multiple types of literacy. As reported in Chan and Kaufman (2011), interrater reliability was calculated for coding of the CTA. Cohen's Kappa for literacy was .91 and Spearman correlation coefficient for cognitive complexity levels was .92, indicating high levels of agreement for both dimensions.

3.3. Cognitive studies of participant performance

Participants

We recruited 20 representative users to perform the specified tasks online. Participants selected were between the ages of 18-65. Participants were drawn from two centres: Union Settlement Association and the Columbia Community Partnership for Health (CCPH). Participants were recruited in partnership with each organization primarily through flyers and word of mouth. IRB approval was obtained through Columbia University.

Data collection

After signing a consent form, participants completed a series of pre-test surveys to collect demographics, skill assessments (health literacy and numeracy), and computer and internet confidence. A demographic survey asked about their educational background, primary language, age group, primary racial group, income (optional), sources of health information, and the number of times they had searched for health information on the Internet. Health literacy was assessed using the Short Test of Functional Health Literacy in Adults (S-TOFHLA) (Baker et al., 1999), a validated test of health literacy that measures patients' comprehension of health texts commonly encountered in the health care setting (Ratzan & Parker, 2006). Numeracy was measured using a validated, 3-item questionnaire that assesses basic familiarity with probability and representation of numbers in different formats (Lipkus, Samsa, & Rimer, 2001). Participants completed a 5-point Likert scale Computer and Internet Survey to gauge their confidence in carrying out common tasks, such as checking email or opening a browser.

Each participant then received one of three sequenced versions of the six eHealth tasks in a randomized order to mitigate any order effects. Participants were asked to verbalize their thoughts (a think-aloud protocol) while completing the tasks. Think-aloud protocols can reveal any hesitation, confusion, or misunderstanding while completing a task. It can reveal insights not obtainable via other methods (Cotton & Gresty, 2006), such as insights into reasoning and decision-making processes. While completing the tasks, the researchers provided guidance only when necessary to help participants complete a task, or to reroute them from a potentially fruitless path.

After the tasks were completed, participants filled out a 10-question Website Usability Survey measured on a 5-point Likert scale. Each session ran from 60 to 120 minutes. Participants were compensated $50 for their time. Each session was audio-recorded, and Morae™ software captured all actions on the computer screen.

Data analysis

We conducted the analysis for six information-seeking and decision-making tasks. Each task comprised 3 questions, for a total of 18 questions. The tasks span a range of topic domains such as hospital ratings and heart attack treatment options. Participants were asked to use the Consumer Reports Health website (http://www.consumerreports.org/health), a resource that provides evidence-based information related to health issues. The website was selected because, in our judgment, it is a high quality site that reflects a genuine understanding of consumers' needs.

Task responses were scored and problems or barriers that participants encountered while completing the tasks were documented. The framework coding was applied to classify the barriers encountered by literacy type and cognitive complexity level. In-depth micro-analysis of 2 of the 6 tasks, Depression task (Fig. 2) and the Exercise task (Fig. 4), is presented in the Results section.

Data analysis of barriers encountered by participants

A step-wise micro-analysis of each participant's performance was done based on the audio recording, video capture, and notes taken during observation of the session. The measures of interest were 1) the correctness of the participant's answer to each task question and 2) the barriers the participant encountered at each step towards completing the task. An answer key for the task questions was developed to ensure consistency in scoring correctness of participants' answers. Responses were scored 0 (Incorrect), 1 (Partially Correct), or 2 (Correct). Barriers, events where participants struggled and may be unable to make progress in the task or may require some problem-solving steps before moving forward in the task, were identified when participants required prompts, verbalized questions, or made errors. A prompt is verbal assistance provided by the researcher to the participant, such as directing them to appropriate information or reminding them about the next step of the task. A question was noted when the participant explicitly requests guidance from the researcher or expressed confusion. An error represents a misstep or misinterpretation of information or system response made by the participant, such as misunderstanding online search results. For each barrier event and answer with score 0 (incorrect) or 1 (partially correct), we applied the framework coding to classify the nature of the participant's problem in terms of literacy type. For example, the barrier event of a participant having difficulty navigating between screens was categorized as difficulty with a computer literacy skill, and the barrier event of a participant struggling with text passages was categorized as difficulty with reading literacy. Finally, each barrier event was matched with the corresponding step in the task completion process in which it occurred.

4. Results

4.1. Participant profile

Twenty participants completed the six tasks. Table 1 summarizes participants' demographic background.

There were more female than male participants, and participants spanned all age ranges from 18-65 with most participants (45%) in the 40-49 age range. Participants generally reported having completed high levels of education with more than half (65%) having college or graduate education. Income ranges were mostly low, with 40% earning less than $10,000. Response to this question was optional; 25% of participants preferred not to disclose their income. More than half (55%) of the participants indicated African American as their primary racial.

Each participant completed assessments of their numeracy and health literacy, as shown in Table 2. Most participants scored highly on health literacy, with 95% of participants scoring "Adequate" and only 5% (one participant) scoring "Inadequate". However, most participants scored low on numeracy, with 80% of participants scoring only 0 or 1 out of 3 possible points. Few participants had never searched for health information online before (10%); over half of the participants recalled having searched for health information online more than 5 times in their lives.

In responses to the Computer & Internet Survey, a majority of participants rated themselves highly on computer and Internet skills. Overall, responses were an average of 3.82 with a standard deviation of 1.15, where anything above 3 represented a positive rating and anything below 3 represented a negative rating. Seven participants responded with mostly 5s, reflecting highest confidence in their computer and Internet skills.

Table 1
Demographic background of participants

	% of participants (n=20)
Gender	
Male	30%
Female	70%
Age groups	
18-29	15%
30-39	10%
40-49	45%
50-59	25%
60-66	5%
Education	
Grade School	0%
High School	35%
College	35%
Graduate School	30%
Income range (optional question)	
<$5000-9999	40%
$10000-29999	15%
$30000-59999	20%
$60000-100000+	0%
No answer	25%
Race	
African American	55%
Hispanic	15%
White Caucasian	10%
No Primary Group	10%
Multiracial	5%
Other	5%

Table2
Skill backgrounds of participants

	% of participants (n=20)
Health Literacy (S-TOFHLA)	
Inadequate	5%
Marginally Adequate	0%
Adequate	95%
Numeracy scores (max=3)	
0	30%
1	50%
2	20%
3	0%
# Times searched for health information online	
Never	10%
<5	25%
5-10	30%
10+	35%

4.2. Participant task performance

Participants ranged widely in their task performance, measured by task scores and number of barriers encountered (as shown in Table 3). P16 scored the lowest across the 6 tasks (10/36) and was the fourth highest in terms of number of barriers encountered (83 barriers). P17 scored the highest in task performance (34/36) and encountered the fewest number of barriers (12 barriers). P10 encountered the most barriers (153 barriers).

Fourteen participants completed the post-test Website Usability Survey asking about their perceptions of usability of the website used to carry out the tasks; participants 1-6 did not receive the survey because it was unavailable at the time. Participants responded to items about perceived usability, such as ease of navigation, organization of content, and clarity of language. Responses were measured on a 5-point Likert scale with 5 reflecting the highest perceived usability and 1 reflecting lowest perceived usability. Twelve participants responded with mostly 4s and 5s. The high responses about perceptions of usability suggest that the barriers encountered were not principally due to problems of the website's usability, but that there were other factors at play.

Table 3
Scores and number of barrier events of all participants

Participant	Total score across 18 questions (max=36)	Average score per question (max = 2)	Total # barrier events
P1	24	1.33 (.69)	49
P2	24	1.33 (.69)	21
P3	28	1.56 (.62)	28
P4	22	1.22 (.88)	65
P5	22	1.22 (.94)	62
P6	30	1.67 (.59)	35
P7	26	1.73 (.59)	32
P8	16	0.89 (.90)	54
P9	16	0.89 (.90)	41
P10	14	0.78 (.81)	153
P11	22	1.22 (.88)	74
P12	31	1.72 (.57)	52
P13	19	1.06 (.87)	85
P14	14	0.78 (.81)	92
P15	14	0.78 (.81)	52
P16	10	0.56 (.70)	83
P17	34	1.89 (.32)	12
P18	15	0.83 (.86)	23
P19	20	1.11 (.90)	30
P20	24	1.33 (0.84)	14
Overall means	21 (SD=7)	1.2 (SD=.8)	53 (SD=34)

4.3. Relationship between participant background and task performance

Correlations were calculated between background measures and performance measures, as shown in Table 4. The Spearman coefficient was selected in order to measure degree of association between the ordinal variables. Barriers and Total Score were negatively correlated (-.59), which is consistent with expectations, as barriers indicate some difficulty with the question whereas high total scores reflect competency in negotiating the question. Health Literacy was highly correlated with Total Score, and in fact these were the most highly correlated variables (0.78). However, there was very little variability in Health Literacy; 95% of participants scored between 31-36. Income, Age and having searched for health information online (HI Online) were also correlated with Total Score. Health Literacy, Computer and Internet skill (Computer/Internet), and Perceived Usability of the website were negatively correlated with Barriers. It is also not surprising that Perceived Usability and Barriers are negatively correlated, as a high assessment of usability reflects perceived ease of use of the system. Perceived Usability was least correlated with Total Score. Perceived Usability was correlated with Computer/Internet as well as Age; this may be explained by the nature of usability questions, which generally ask about interaction with the system, which reflects Computer/Internet knowledge and skills. It is surprising that Numeracy was not correlated with Total Score or Barriers, as many of the barrier events stemmed from numeracy-related difficulties.

Table 4
Correlation between assessments and participants' task performance, calculated using Spearman's rho and rounded to 2 decimal points. (*= significant at .05 level; ** = significant at .01 level)

	Health Literacy	**Computer Internet**	**PU**	**Gender**	**Age**
Numeracy	0.39	-0.02	0.04	-0.08	0.03
Health Literacy		0.07	0.13	-0.32	0.27
Computer/ Internet			0.72**	0.26	-0.41
Perceived Usability				0.25	-0.58*
Gender					-0.23

	Income	**Education**	**HI online**	**Total Score**	**Barrier events**
Numeracy	-0.07	0.35	0.10	0.36	-0.19
Health Literacy	0.38	0.67**	0.38	0.78**	-0.56*
Computer/ Internet	0.21	-0.23	0.42	0.20	-0.56*
Perceived Usability	-0.08	-0.18	0.16	0.01	-0.55*
Gender	-0.41	-0.64**	-0.44	-0.32	-0.24
Age	-0.10	0.17	0.14	0.18	0.31
Income		0.26	0.22	0.63**	-0.38
Education			0.34	0.54*	-0.08
HI online				0.58*	-0.23
Total Score					-0.59*

4.4. Aggregate participant performance

Each participant was given 6 tasks, each comprising 3 questions. One participant did not complete the Exercise task; the rest of the participants completed all tasks given. Across all 18 questions, questions Heart Attack C and Hospital Ratings B were answered correctly by more participants than any other question, with 16 correct answers for each of these questions (Fig. 1). No participant correctly answered question Depression C (Fig. 1). The Heart Attack task had the most correct answers across the three questions (38 correct across A, B, and C), followed by the Exercise task (33 correct across questions A, B, and C). Depression task had the fewest correct answers (20 correct across questions A, B, and C). The Depression and Exercise tasks are presented in more detail to investigate the difficulties that participants had with these questions in particular. These two tasks were selected because they require different types of eHealth literacy demands and different levels of cognitive complexities. Additionally, participants' performance between the two tasks showed variation in scores and in types of barrier events.

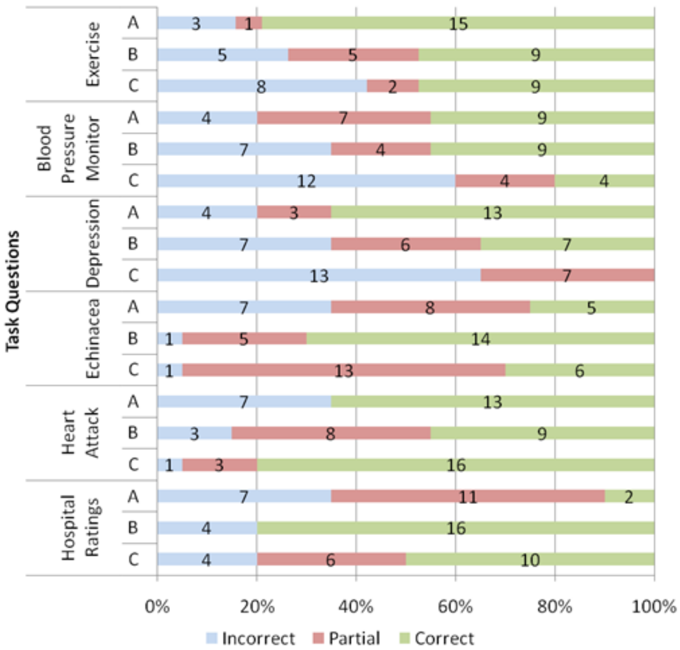

Fig. 1. Participant scores on 18 questions; each of the 6 tasks consisted of 3 questions (A, B, and C)

4.5. Depression task

CTA results

The cognitive task analysis for this task revealed the eHealth literacies and cognitive complexity levels required to answer each question (Table 5). Question B required a combination of more eHealth literacy types than Questions A or C, and is the only question to require Science literacy, which is used to identify and pick out information sources within the reference list. Of the 3 questions, Question C required the highest cognitive complexity level for writing literacy (Evaluating), which was used to articulate their evaluation of the article's credibility. Question A is the only question to require health literacy, which was used to identify questions related to treatment options. Information literacy and reading literacy were both required to identify the appropriate information to meet the information need, and these literacies are used in all 3 questions. Media literacy is used in both Questions B and C to recognize and analyse the article's references. The highest cognitive complexity required across the whole task is Evaluating (level 5) for information literacy, which was required for each of the 3 questions.

Depression task

You have an upcoming appointment with your doctor, and you want to discuss possible depression symptoms. Use the resources under "Conditions and Treatments" to learn more about depression.

A. Look for some questions to ask your doctor related to treatment options.

B. Look for the article on how depression is diagnosed. Does this article cite any references? If so, where are these references from?

C. What features on this website influence your decision about whether the information in the article is credible?

Fig. 2. Depression task questions

Table 5
Depression task: Summary of CTA results

Literacy	Question A	Question B	Question C	Whole task
Media Literacy	0% N/A	67% Apply (3)	100% Analyse (4)	33% Analyse (4)
Computer Literacy	50% Apply (3)	33% Apply (3)	0% N/A	44% Apply (3)
Health Literacy	50% Analyse (4)	0% N/A	0% N/A	33% Analyse (4)
Information Literacy	100% Evaluate (5)	100% Evaluate (5)	100% Evaluate (5)	100% Evaluate (5)
Reading	100% Understand (2)	100% Understand (2)	100% Understand (2)	100% Understand (2)
Writing	50% Apply (3)	33% Understand (2)	100% Evaluate (5)	33% Evaluate (5)
Numeracy	0% N/A	0% N/A	0% N/A	0% N/A
Science Literacy	0% N/A	33% Understand (2)	0% N/A	11% Understand (2)
Total # steps	2 steps	3 steps	1 step	9 steps*

* Total # steps for whole task includes a series of navigational steps leading up to Questions A, B, and C.
For the task, the following is displayed: the proportion of steps that utilize that eHealth literacy (percentage in top half of cell) and the highest level of cognitive complexity used in that literacy (number and complexity level in bottom half of cell).

Participant task performance

Table 6
Depression task: Detailed description of P6 performing steps 4-6

Task Question	Step	Skills/knowledge associated with step	Code from CTA (Literacy type and Cognitive Complexity Level)	Events that indicate barriers Time (min), Action	Code for barrier (Literacy type and Cognitive Complexity Level)
A	**4**	Segment page, recognize menu of topics across top, and click on "Questions to ask" as appropriate link to meeting information need	Information 3 Reading 1 Computer 3	35:35 Participant rereads the question and asks for clarification, “Ok, well these are questions to ask, right?” Participant prompted: “Are there particular ones related to treatment options?	Information 1
A	**5**	Read list of questions and selected some questions related to treatment options, or come up with some related questions	Information 5 Reading 2 Health 4 Writing 3	35:39 Participant lists 5 relevant questions from the list. (Score = 2, correct)	
B	**6**	Recognize "How is it diagnosed" as meeting info need, click on link to article	Information 3 Reading 1 Computer 3	36:56 Participant is unsure where to find information about diagnosis for depression. Participant scrolls up and down the page, browsing the links and resources. Clicks link for *Key Points about Treatments.*	Information 3
				38:02 Participant keeps clicking around, unable to find the appropriate link. Participant asks, “I’m going to need your help. I'm looking for an article called Depression is Diagnosed.” Participant rereads question. “Oh, on how it’s diagnosed? That means how it’s treated right?”	Information 3 Health 1
				38:26 Participant prompted: “No, we are looking at diagnosis.”	Information 2 Health 1

For Question A, participants had 13 correct answers, the highest of the 3 questions (Fig. 1). Participants scored lowest on Question C, with no correct answers and over half of the answers were incorrect (Fig. 1). One possible reason that may have contributed to the low number of correct answers for Questions B and C is that they require media literacy and science literacy at high cognitive complexity levels (Table 5). Many incorrect answers were due to participants not recognizing the information reference(s) on the page; rather they commented on how the information was presented or what they perceived as the message. For example, many cited that the information comes from doctors even though this is not stated anywhere on the webpage. Also, most evaluated the quality of the information based on their own understanding of the topic domain or their own experience rather than using external criteria (e.g., credibility of the references). Some participants commented that a piece of information seems accurate because it echoes an anecdote they had heard or a particular experience from their past. For Question C, some participants needed the question explained or elaborated; one participant didn't know the meaning of the word 'credible'. These are some examples of barriers that likely contributed to the low number of correct answers to Questions B and C.

An excerpt of Participant P6's task performance on steps 4-6, a series of steps in Questions A and B, of the Depression task is shown in Table 6. The participant scored well across all three questions, with a total score of 4/6 points. The participant encountered four barriers during this excerpt; all barriers involved struggle with information literacy, ranging from levels 1-3. In step 4, the participant did not fully recognize (level 1) the information need and asked for clarification. During step 6, the barriers encountered reflected the fact that the participant didn't fully understand (level 2) the information presented in order to identify (level 3) the appropriate resources. Two of the four barriers encountered also involved health literacy, because the participant was confused by the difference between diagnosis and treatment, two health concepts. Ultimately, the participant did provide the correct answer to Questions A and B.

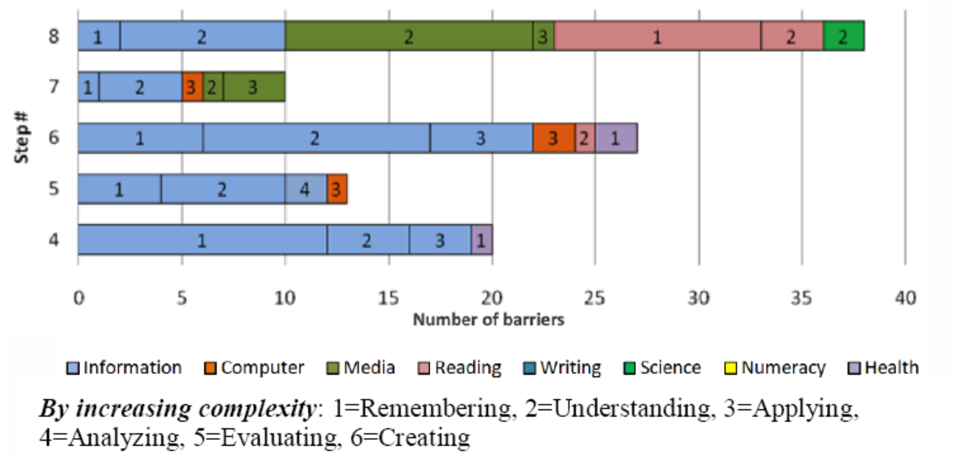

Fig. 3. Depression task: barriers encountered by all participants in steps 4-8, categorized by literacy (color in legend) and cognitive complexity level (number in the graph)

The total number of barriers for all participants in Questions A and B (steps 4-8) in the Depression task are displayed in Fig. 3. Most of the barriers in Question A (steps 4-5) are classified as information literacy; participants had trouble recognizing (level 1) the information need and finding (level 3) the link to "Questions to ask". The comparatively few computer-related barriers were due to prompts to the participant to scroll for additional information. Many of the barriers encountered in Question B were also due to information literacy, but there was more variation of other types of literacy barriers (Fig. 3). In step 6, most participants did not immediately recognize (level 1) the link to the article "How is it diagnosed". In Question B, participants needed to read the article and identify the references cited by the article in order to answer the question. Some participants confused references with referrals and cited text from the "Referrals to specialists" as sources of information on the page (a failure to recognize references –

media literacy, level 2). In this misunderstanding, they also failed to understand (level 2) the passages, which do not describe any sources of information. Most of the barriers in Question C were related to both information and media literacy. A few participants cited referrals as references and doctors as the source of references, adding that doctors are the only ones capable of providing references on depression. These incorrect answers reflect misunderstanding of references as well as the range of reliable sources of information available; this is evident in the numerous classifications of media literacy barriers in steps 7 and 8.

Of the 6 tasks, participants generally scored worst on this task; it was difficult for high and low scorers alike. The low performance could be due to the fact that the Depression task is the only one to require media literacy at high cognitive complexity levels.

4.6. Exercise task

Exercise task

You are a 56-year-old female, and you would like to start doing regular physical activity. Use the "Healthy Living" resources to read more about exercise and fitness options. There are a few fitness tests available to test fitness levels.

A. When you test your aerobic fitness, you find that you are able to walk one mile in 15 minutes and 26 seconds. How does your result compare to the results of the aerobic fitness test?

B. To improve your aerobic fitness, you decide to walk regularly as part of your workout. In the article on "Walking Workout", what are 2 workout accessories that you would need to purchase to improve your workout?

C. You consider purchasing a treadmill at home to do your walking workout, and explore the articles on treadmills on the website. Which treadmills are recommended as Consumer Report's "Best Buys"?

Fig. 4. Exercise task questions

CTA results

Unlike the Depression task, participants generally scored well on the Exercise task, which is presented in Fig. 4. The literacy requirements for the task, summarized in Table 7, show that information and reading literacy were both required most frequently (95%) and were required across all 3 questions. No media or science literacy was required to complete this task. Computer literacy was also required often (63%) to navigate the website and find appropriate resources. Reading literacy was required at a higher complexity for Question C than in Questions A and B. While Questions A and B ask users to extract and use some information from text, Question C asks users to integrate pieces of information about treadmills and about ratings. Question B generally required the highest cognitive complexity levels. Numeracy was required at level 4 (Analysing) for both Questions A and C, to interpret exercise results and treadmill ratings that were presented in a table. Most literacy types were required at level 3 (Applying). The highest cognitive complexity required was Evaluating (level 5), for information literacy, and was only required at level 5 for one question. This task can be considered a task of low/intermediate complexity because it did not require the widest range of literacies, and most literacies were only required at cognitive complexity levels between 2 to 4.

Table 7
Exercise task: Summary of CTA results

Literacy	Question A	Question B	Question C	Whole task
Media Literacy	0%	0%	0%	0%
	N/A	N/A	N/A	N/A
Computer Literacy	50%	75%	67%	63%
	Apply (3)	Apply (3)	Apply (3)	Apply (3)
Health Literacy	17%	50%	0%	21%
	Remember (1)	Apply (3)	N/A	Apply (3)
Information Literacy	100%	75%	100%	95%
	Analyse (4)	Evaluate (5)	Analyse (4)	Evaluate (5)
Reading	100%	100%	83%	95%
	Understand (2)	Apply (3)	Analyse (4)	Analyse (4)
Writing	17%	25%	17%	16%
	Understand (2)	Apply (3)	Understand (2)	Apply (3)
Numeracy	67%	0%	17%	26%
	Analyse(4)	N/A	Analyse (4)	Analyse (4)
Science Literacy	0%	0%	0%	0%
	N/A	N/A	N/A	N/A
Total # steps	6	4	6	19

For the task, the following is displayed: the proportion of steps that utilize that eHealth literacy (percentage in top half of cell) and the highest level of cognitive complexity used in that literacy (number and complexity level in bottom half of cell).

Participant task performance

Participants scored very well on Question A, with 15 correct answers (see Fig. 1). Participants also scored well on Questions B and C, with 9 correct answers (see Fig. 1). However, Question C had 8 incorrect answers while Question B had 5 incorrect answers. Questions A and C had similar demands, but Questions B and C had the most similar scores by participants. During Question C, some participants that did not closely scrutinize the table had difficulty finding the “CR Best Buy” label. This type of barrier reflects difficulty with both numeracy and information literacy because participants had to extract relevant information that was presented in a tabular format. Although participants scored well on Question A, as a group they also encountered the most barriers in trying to answer this question. Participants struggled with the component steps that required them to understand (level 2) the question (e.g., did not know they had to look for information about fitness tests in order to begin to answer Question A), segment (level 3) the webpage to find the appropriate menu selection (e.g., they had difficulty identifying and recognizing the “fitness tests” link as the entry point to finding the answer to Question A), and interpret (level 4) the resources effectively (e.g., compare their results with the aerobic fitness rating levels).

Table 8
Exercise task (question c): Detailed description of P10 performing steps 16-19

Step	Skills knowledge associated with step	Code from CTA (Literacy type and Cognitive Complexity Level)	Events that indicate barriers	Code for barrier (Literacy type and Cognitive Complexity Level)
16	Read the article on treadmill ratings, recognize that CR identified 3 "Best Buys"	Reading 4 Information 3	15:18 Participant is confused, saying "But it's saying to go to Best Buy" interprets 'CR Best Buy' as having to go to the Best Buy store	Reading 2
			15:22 It is explained to the participant what "CR best buy" label means, and that it does not refer to the Best Buy store	Reading 2
			15:47 Participant points to video on the page, and asks "Do I have to click on video?"	Information 2
			15:53 Participant is informed, "You don't have to." Participant clicks the play button to watch the video.	Information 2
			17:06 While watching the video, participant asks about some information from the video, "They test the treadmill with a 170 pound runner, but what if you are heavier than that?"	Science 3 Information 5
			17:15 It is explained that 170 is just the standard test weight for that test.	Science 3 Information 5
			17:57 Participant stops the video and asks, "So what are we looking for? I lost track. Oh the purchase right?	Information 1
			18:20 Participant browses the article and asks "I have to pick from here, right?"	Information 2
17	Recognize info need as looking for Treadmill ratings, and click on "recommended" or "ratings" for treadmills	Computer 3 Reading 1 Information 3	18:25 Participant prompted, "You want to look at either the recommendations or the ratings?"	Information 3
			18:31 Participant responds, "Both. You gotta look for both of them." Participant prompted, "OK, try one". Participant clicked on *Recommended*.	Reading 1 Information 3
18	Scroll down to see full table. Recognize results as a table of ratings for treadmill products	Information 4 Numeracy 4 Computer 3	Participant scrolls down and tries to interpret the table of recommendations	
19	Look for "Best Buys" label and identify all 3 treadmills labeled "Best Buys"	Reading 2 Writing 2 Information 4	19:01 Participant is prompted, "So do they call any of these best buys?"	Information 1
			19:12 Participant provides answer, "These two right here – Pacemaster and Epic View" (Score= 1, partial)	Numeracy 4 Reading 3 Information 3

Table 8 displays an excerpt from participant P10's task performance in steps 16-19 of the Exercise task, which are steps leading to the answer for Question C. P10 struggled with this task, scoring only 1/6 points across the three questions and encountering a total of 35 barriers. In step 16, the participant struggled with multiple literacy types. The first set of barriers resulted from not understanding (level 2) the text, that "Best Buy" is a label created and applied by CR, and does not indicate that the reader go to the Best Buy store to purchase the best treadmills. The next set of barriers resulted from being uncertain of what resources would meet the information need, and missing information cues on the webpage. The participant then clicked on the video rather than reading the text of the article. The participant asked a question about information from the video. This reflects evaluation (level 5) of information learned, and also an attempt to contextualize (level 3) the information to inform the decision about whether this resource is relevant and appropriate to answering Question C. After the video, the participant returns to the article; the participant forgot (level 1) the question and failed to understand (level 2) that the question asks for treadmill names, which are not listed in the body of the article. In step 17, P10 is prompted by a researcher to refer to recommendations or ratings (information literacy - level 3), which are the appropriate information cues. The participant didn't recognize the distinction between ratings and recommendations. Finally, in step 19, the participant needed another prompt to focus on the question and information need (information literacy – level 1). The participant's answer to Question C was partially correct because only 2 of the 3 treadmills labelled "CR Best Buy" were identified. The participant failed to recognize that the article in the previous webpage stated that three treadmills were identified, which was categorized as a barrier in numeracy at level 4 (did not fully interpret the table of treadmill ratings), reading literacy at level 3 (did not use all of the text available), and information literacy at level 3 (did not fully respond to the question).

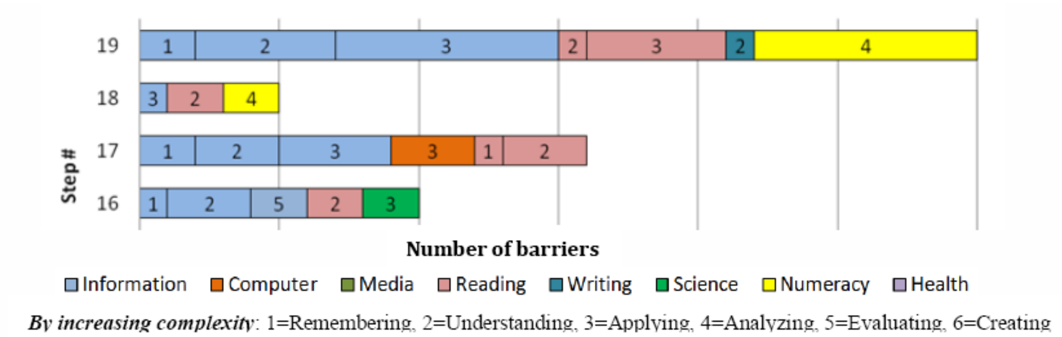

Fig. 5. Exercise task: Barriers encountered by all participants in steps 16-19, categorized by literacy (colour in legend) and cognitive complexity level (number in the graph)

The types of barriers encountered across all participants in Question C of the Exercise task are displayed in Fig. 5. Participants collectively encountered more barriers in steps 17 (16 barriers) and 19 (30 barriers), with at least half of the barriers attributed to information literacy. In step 17, participants needed to click on either the "recommended" or "ratings" link to see the actual ratings for the treadmills. Similar to P10's barriers described above, some participants failed to realize that they needed to look for the "recommended" or "ratings" link (barrier in information literacy at level 3). Others had difficulty finding the links (a barrier in information literacy at level 3). Still others failed to understand that the article did not provide the actual ratings (barrier in information literacy at level 2), which was apparent when they described the criteria considered for rating instead of seeking the actual ratings. In step 19, participants needed to select the columns that contain the information they are looking for, look for the label "CR Best Buy", and identify the three treadmills that have that label. Many participants failed to recognize "CR Best Buy", since the text label did not stand out. Many participants also were confused by the table headings and legend, and struggled to interpret the table ratings (barriers in reading literacy and numeracy). Overall, participants performed well on the Exercise task, which primarily required information and reading literacy.

5. Discussion

In prior work, we proposed a novel framework-based micro-analytic methodology to classify task demands and user performance on eHealth tasks (Chan-Kaufman framework). Task demands are classified by literacy type and cognitive complexity level, and provide a measure independent of user performance, which was quantified by task score and number of barriers the user encountered during the task. The objective of this study was to apply the methodology to reveal task demands and diagnose barriers that 20 participants encountered while performing six information-seeking and decision-making tasks. In the analysis, we scored participants' answers, identified barrier events that users encountered during the task, and classified barrier events and incorrect and partially correct answers using the framework methodology.

5.1. Insight into demands of the tasks by literacy and cognitive complexity

The analysis characterized task demands, representing the demands by literacy type and by complexity. The method provided a systematic way to characterize and analyse each demand, as well as to compare and contrast users' task performance across tasks of varying demands. Based on the framework, all six tasks in this study are of medium difficulty, as none of them required any literacy type at the highest cognitive complexity level (level 6). Reading and information literacy were the most frequently required literacy types across all tasks.

Information literacy is a prominent topic in information seeking literature, and it is a critical component to the effective use of eHealth (Catts & Lau, 2008). Participants as a whole faced the most number of barriers in information literacy. The most frequently encountered barriers were forgetting the information needed to answer the question or forgetting the task question altogether, failing to identify relevant links and cues on the website, and failing to identify appropriate information. For example, in the task that asked about results of a fitness test, most participants failed to recognize that the link to "fitness tests" was under the "staying fit" menu of the Exercise and Fitness webpage. Another example, from the Depression task, is that some participants were not certain what to look for when trying to find an article about how depression is diagnosed. They would scroll up and down and click randomly on links until they eventually clicked on the link labelled "How is it diagnosed". In this case, participants' disorganized and uncertain strategy was a sign that they had difficulty understanding the question. Participants who did not face this barrier had a strategy such as thinking through various words or phrases associated with "diagnosis" to help them narrow their search for the answer to how depression is diagnosed. This may suggest the importance of educating health consumers in a foundation of basic medical terminology or providing ways to enhance their information literacy skills and to be more effective in their use of search strategies. The fact the many participants faced barriers in low-level information and reading literacy due to challenges in understanding basic medical vocabulary may support the need to incorporate this vocabulary into primary-education.

Numeracy has been an issue of critical importance in how healthcare consumers understand, use, and interpret health information (Ancker & Kaufman, 2007). Many of the numeracy-related demands in our study presented information in tabular form, and most participants did encounter barriers with those interactions. In line with previous work on numeracy demands, the results from our study suggest that tabular presentation of evidence may be confusing and an alternative representation that is more effective should be considered.

An important component of eHealth literacy is media literacy, which usually introduces significant barriers for a majority of people when searching and evaluating health information. As previously found in related literature (Knapp et al., 2011; Manafò & Wong, 2012; Subramaniam et al., 2015), our study also revealed that evaluating trustworthiness and credibility of health information is a common media literacy barrier. For example, many participants in our study experienced barriers when identifying and applying appropriate criteria to evaluate the information source. Some participants suggested information sources that were not based on evidence. For example, some believed that all the information on the website was written by doctors, a trusted source, although that was not stated anywhere on the website. A few participants were very sceptical of the information presented due to other factors such as distrust of the field of medicine and concern that funding sources influenced website content. These findings reflect that media literacy in the context of health information still poses significant barriers for many people, and support the need for engaging more resources to help promote these skills.

There is a widely documented gap between demands of tools and the skills and knowledge of target users. Our approach addresses gaps in a way that traditional usability studies do not reveal. There is literature that explores each of these literacies, but few research efforts study and discuss all of them together. Through the use of this methodological framework we show that an integrated approach can be an informative way to represent and describe task demands. Through this analysis, we were able to describe the configuration of combinations of literacy types at play at different steps of task completion. It should be noted that the obstacles confronted by users, as measured by levels of cognitive complexity, sometimes differed from those characterized by the CTA performed by analysts. This is analogous to the fact that usability testing often yields somewhat different results than usability inspection methods (Kaufman et al., 2003). In combination, the two methods provide complementary findings and yield a richer picture of the challenges confronted by the users of an eHealth tool.

Our micro-analytic approach also helps reveal new potential methods to measure and observe the literacies. We found that insight into participants' computer literacy was observable whereas numeracy required think-aloud protocol to reveal participants' understanding of numeracy concepts.

5.2. Insight into participants' skills (individual and group)

Task performance helped to reveal insight into the skills of particular participants and of all participants as a group. Our methodology was effective at diagnosing why some participants had low scores or encountered many barriers; the framework coding was able to identify the literacy types and cognitive complexity levels that led to those barriers or incorrect answers. The analysis showed the distribution of task scores and barriers for each participant, which uncovered deeper insight into participants' skills. Mapping barriers to literacy types helped to identify more targeted solution strategies as well as provided deeper understanding of the interaction between users and eHealth tasks. The analysis can identify gaps in users' skills and knowledge as well as predict potential barriers.

The breakdown of barriers by participant was also able to reveal which literacies and barriers were problematic for most participants or for just a subset of participants. These results help to predict potential difficulties for a wider range of users as well as identify target areas for solution strategies. Additionally, the results can further inform which education objectives are most applicable to a wide range of eHealth users.

5.3. Insight into task difficulty

Task scores helped to identify which questions were most problematic for participants. Further, comparing scores with demands determined in the CTA helped classify certain demands as difficult, based on participants' actual performance. Analysis showed that barriers were not distributed evenly across steps; for each task there were usually 2 or 3 steps in which participants encountered the most number of barriers. The analysis was able to reveal those problematic steps in each of the tasks, and explore why these particular steps caused the most barriers. The analysis was also able to reveal which steps were problematic for most participants or just a few participants. The aggregate results identified which literacy types and complexity levels are associated with the most number of barriers across all participants and tasks.

5.4. Limitations

This study analysed tasks that involved information-seeking and decision-making activities. Applying this analytic method to other types of eHealth activities, such as use of patient portals or chronic disease management, could reveal a different distribution of eHealth literacy demands with varying cognitive complexities. The number of participants was small, which may limit the generalization of the study findings. However, we have conducted a rather in-depth quantitative and qualitative data analysis from 20 participants.

5.5. Future work

Although the methods outlined in this paper have the potential to yield substantial insight into eHealth literacy and inform design, the analysis is very time-consuming and requires substantial expertise. We anticipate that future work will include the development of a wizard-like guided system that presents a series of questions to analysts, designers and developers that will reveal the kinds of barriers that their users may confront. We envision a set of queries that are analogous to a heuristic evaluation (Nielsen, 1994) but with a focus on eHealth principles rather than usability principles.

The current literature on eHealth literacy, including the work presented in this paper, is too narrowly focused on information-seeking tasks. The world of eHealth is changing as evidenced by the proliferation of social media (Norman, 2011). This surfaces other cognitive and social skills including communication that needs to be addressed. In addition, patients with chronic illnesses need to develop a better understanding of their condition and this involves a greater level of scientific literacy. For example, we expect that patients with diabetes may be better able to productively use eHealth health management tools if they have a greater understanding of glucose metabolism.

6. Conclusion

There are many cognitive and noncognitive factors at play in the interaction between a user and eHealth tool; this approach looks specifically at literacy and cognitive skills and barriers. However, this approach applies a systematic analysis to make this slice more tractable. In this study, we focus on relatively discrete steps and questions as units of measure; however, in actuality, the steps and questions are not independent of each other. There are interdependencies between steps and questions within a task, and possibly between tasks as well. The literacies are also synergistic; for example, computer literacy demands will limit the cognitive resources available to juggle the other demands within a step, such as information literacy demands. Further analysis will explore more deeply the relationships among the literacies, complexities, and task questions.

Kayser et al. (2015) proposed a comprehensive approach to eHealth literacy that shines a light on task and context. Our approach embraces a deep-dive into knowledge and cognitive skill. We see the two approaches as complementary in developing a comprehensive approach to inform the design of effective eHealth technologies based on an understanding of the needs of consumers and patients.

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