Afraid to Ask: Proactive Assistance with Healthcare Documents Using Eye Tracking

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CHI 2014, April 26–May 1, 2014, Toronto, Ontario, Canada.

ACM 978-1-4503-2473-1/14/04.

Abstract
We investigate gaze patterns and other nonverbal behavior that people use when providing and receiving explanations of complex healthcare documents, and use a model of this behavior as the basis of a system that provides automated, proactive assistance. We present the results of the human analog study along with results from a preliminary evaluation of the automated system. We also demonstrate the feasibility of using eye tracking to automatically assess the health literacy of people reading healthcare documents.

Author Keywords
Health literacy; gaze tracking; conversational agents.

ACM Classification Keywords
FIXME: H.5.2. Information interfaces and presentation: User Interfaces – Interaction styles – Gaze; Graphical user interfaces, Interaction styles. J.3 [Computer Applications] Life and Medical Sciences – Health, Medical Information Systems.

Introduction
Ninety million Americans have inadequate health literacy, resulting in a reduced ability to obtain, process, and understand basic health information and

services needed to make appropriate health decisions [13]. Limited health literacy has been associated with less health knowledge, worse self-management skills, higher hospitalization rates, poorer health, and greater mortality. Individuals with low health literacy are also much less likely to ask questions of health professionals in order to get the information they need to take care of themselves [12].

Although a significant amount of research has been conducted on health literacy, the majority of this work has focused on correlational studies describing patterns of association with health literacy [14], with very little work exploring interventions to address the condition. Several tools have also been developed to assess health literacy (e.g., [9]), but these are almost all paper-based instruments that must be manually administered by a clinician or researcher. Most of them take between three and seven minutes to administer and can cause feelings of shame, particularly for people who do not perform well on these assessments [15].

In this work, we seek to use eye tracking to understand how individuals with low health literacy process and understand healthcare documents. We also seek to understand the verbal and nonverbal behavior used by an individual when receiving explanations of healthcare documents, and use a model of this behavior in a pedagogical agent-based system that explains healthcare documents to users, proactively offering help based on their gaze behavior. We also try to develop a method to automatically assess people's health literacy level based on their gaze behavior while reading a healthcare document, as this would be more efficient and presumably more accurate than traditional paper-based instruments, causing no awkward feelings.

Related Work

Research on the use of eye tracking to infer the cognitive processes underlying reading data primarily dated to the 1970's [16]. Fundamental findings are that people's eyes do not move continuously while they read, but rather jump (saccade) between fixations, and that the duration of gaze fixation and the frequency of regressions increase as text becomes more conceptually difficult.

Gaze has also been found to play a critical role in face-to-face conversation, to convey turn-taking cues [10], to point at things ("deictic" function), and as part of greeting rituals. It also plays a crucial role in "grounding", which is the process by which a speaker and hearer agree upon the meaning of utterances [8].

The Text 2.0 project has focused on providing a range of augmented reading experiences by using eye tracking while users read digitized documents on a computer monitor. Examples include automatically displaying word translations or definitions if a user is struggling (triggered by long fixations), and combining gaze with automatic speech recognition to respond to explicit user requests [6]. The iDict project has also investigated the use of gaze tracking while reading to offer users real-time word translations.[11]

Bickmore, et al, have conducted studies of the verbal and nonverbal behavior used by clinicians explaining medical documents to patients, and have constructed embodied conversational agent (ECA)-based models of this behavior [5]. They have found that patients learn more with ECAs compared to other modalities (such as human instructors), regardless of health literacy, and that individuals with low health literacy generally report

Figure 1. RA Explaining Document to Participant

	Relative to Utterance		
Gaze At	**Start**	**Middle**	**End**
RA	26%	32%	42%
Document	69%	68%	58%
Other	5%	0%	0%

Table 1. User gaze during question-asking.

higher levels of satisfaction with ECAs and ask more questions with ECAs compared to individuals with adequate health literacy [2, 4].

Bass, et al, recently reported a study using eye tracking to observe how individuals with low health literacy process written health messages before and after the text had been tailored for their reading level. Their preliminary findings indicated that individuals with low health literacy process a much smaller portion of the message contents when presented with non-tailored messages compared to tailored ones [1].

Study of Human Helping Behavior

We investigated the verbal and nonverbal behavior used by someone receiving an explanation of a healthcare document, with a particular focus on gaze and question-asking behavior. We selected an informed consent document for an oncology clinical trial that was particularly complex, and had a research assistant (RA) familiarize herself with all information related to the trial. Participants were told they were to read and understand the document as well as they could, and that they could ask any questions of the RA (Figure 1). Sessions were videotaped, all utterances transcribed, and participant gaze and gesture behavior were coded.

Nine individuals participated in the study, 65% female, aged 22-63, 33% low health literacy (based on REALM score [9]). Sessions lasted an average of 11.5 minutes. Only five participants asked any questions. Of those who did ask questions, they asked an average of 3.8 per session (range 2-11). Table 1 shows their gaze behavior during question-asking. The findings indicate that gazing at a helper may be a cue to provide assistance 26% to 42% of the time. Participants also frequently pointed at the document during question-asking 47% of the time.

Design of a Proactive Help System

Based on our observations of natural question-asking behavior, review of the literature, and our prior work, we designed an automated system to explain informed consent documents. We had previously found that ECAs that simulate face-to-face conversation were particularly well-accepted by individuals with low health literacy [2, 3], thus we started with an ECA system designed to explain informed consent documents (Figure 2), and augmented it with input from an eye tracker (Tobii X60) using the Text 2.0 framework [6] (Figure 2). Based on prior work [6, 11] we modified the ECA so that if users fixated on a health related term for longer than 600ms, the agent would proactively offer an explanation of the term. Based on our study in which participants were seen to gaze at the RA 26-42% of the time when they needed help, we also augmented the system so that the agent would proactively offer an explanation of the last health related term looked at when the user “looked for help” by fixating on the agent for longer than 1000ms. Following an explanation (or if the user gazed away from the document), the agent would look at the document and briefly gesture at the location the user left off in an attempt to re-orient them to the document.

Evaluation of the Proactive Help System

We conducted a preliminary evaluation of the gaze-based proactive document explanation system (GAZE), by comparing it to the same system with the gaze features ablated (NOGAZE), and a version without any ECA (CONTROL), in a 3-arm within-subjects experiment. We created three informed consent

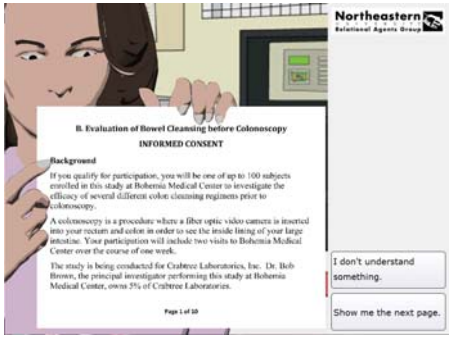

Figure 2. ECA Explaining Document to Participant

documents for colonoscopy clinical trials that were similar in length and complexity but varied in their details. We randomized the order in which the study conditions were experienced by each participant while holding the order of presentation of the three documents constant, to counterbalance both order effects and the effects of any particular informed consent document. Participants completed three rounds of document explanation, filling out comprehension and satisfaction questionnaires after each. Finally, a semi-structured interview was held with them about their experience. Measures included 12-item multiple-choice knowledge tests for each document, and single scale-item questions per Table 2. Sixteen participants were recruited: 56% female, aged 52.3 (range 24-67), 38% low health literacy (based on REALM score [9]).

			Means			
Measure	**Anchor 1**	**Anchor 7**	**CONTROL**	**NOGAZE**	**GAZE**	**Sig (p)**
How satisfied were you with the agent?	Not at all	Very		5.57	4.36	<.05
How much information did you receive?	Too little	Too much	5.00	4.86	4.93	ns
How likely were you to sign the consent?	Extremely unlikely	Extremely likely	5.50	5.07	5.57	ns
How much pressure did you feel to sign the consent?	No pressure	Extreme pressure	2.64	2.57	2.21	ns
Knowledge test score (% correct)			83%	80%	79%	ns

Table 2. Evaluation Study Measures and Results

Scale questions tested using non-parametric tests; Knowledge test using repeated measures ANOVA

In the GAZE condition, participants triggered proactive help an average of 7.1 times, although these were all triggered by long fixations on terms. Participants did gaze at the agent (1.4 times per session) but these did not trigger proactive explanations. In these cases, either fixations were not long enough to trigger any help, or fixations at agent were not preceded by a fixation on a health related term.

Results showed few significant differences between conditions (Table 2), likely due to the small number of participants in the pilot study. There was a significant interaction between study condition and literacy level, such that participants with high health literacy tended to do better with the GAZE agent while low health literacy participants tended to do worse, $F(1,12)=8.7$, $p<.05$. Comprehension was lower for low health literacy participants across all conditions. The only other significant result was that all participants had lower satisfaction with the GAZE condition compared to the NOGAZE condition.

Analysis of post-test interviews indicated that 54% of respondents preferred the CONTROL condition and only one participant (8%) preferred the GAZE agent. The most frequently cited reason that participants did not prefer the GAZE agent was that they found the proactive help distracting (5 respondents). Two participants stated that the timing was off ("...she was either ahead or behind of where I was.", "I'm a fast reader...she was all in the way"), and one volunteered that the orienting hand gesture on the page obstructed their reading. Other reasons were that they "just liked reading" (3 respondents), didn't like computers in general (3 respondents, including 2 low literacy), or found the information provided by the agent unhelpful (2 respondents). However, 29% of respondents volunteered that they liked the idea of having an agent help them with the documents ("It's a good idea as opposed to just reading, staring at a blank page. Like even though they're not a real person you feel like you are being walked through it.").

Assessment of Health Literacy using Gaze

We conducted an exploratory data analysis to determine whether we could assess health literacy based on user gaze behavior while reading a medical document. During the study session described in the previous section, participants' fixations were also recorded while reading a single page of instructions (grade 5-6 reading level, based on Dale-Chall score [7]) followed by a page describing a complex oncology clinical trial. Forty health related terms on the second page were rated for complexity by an expert in health literacy, and the number and total duration of fixations on these terms per participant were computed. Similar terms on the first page were also analyzed to obtain a baseline reading behavior. Eleven features were computed from these metrics and used to predict REALM score and health literacy classification. Using basic regression models we demonstrated an R^2=0.63 and a binary classification accuracy of 85%, indicating the feasibility of this approach.

Conclusion

The human helping behavior we investigated indicated that participants tended to look at either the document or the RA when receiving explanations of healthcare documents. Based on this model, we designed an ECA system which would proactively offer explanation of a health related term when users either gazed at the term or at the agent. A preliminary evaluation of the ECA system suggested participants were more satisfied with the NOGAZE agent compared to the proactive agent. This may have been due to inappropriate timing parameters for triggering explanations of terms, inadequacies in the explanations offered, or inaccuracies in eye tracking resulting in help being offered on the wrong terms. Alternative explanations of our findings to explore include insufficient training about the "look for help" function, insufficient motivation for comprehension in a simulated informed consent scenario, or the possibility that people have very low expectations and aspirations to actually understand consent documents. Nevertheless, about one-third of participants expressed that they liked the idea of having an agent walk them through the medical documents.

Using eye tracking was demonstrated to be a feasible way to automatically assess the health literacy of people reading healthcare documents. While further refinement and validation of this mode of health literacy assessment is needed, this approach would represent a breakthrough as this could possibly remove the burden of time and stigma typically associated with such testing.

Future work includes continuing to tune the timing parameters of the proactive agent. In particular, this feature can be personalized to adapt to the user's reading speed. We believe the reason that low literacy participants performed particularly poorly was that their slower reading speed triggered the proactive help more frequently than needed. Additional adaptation of the support system will include options for explanation support that goes beyond explanation of terms to include conceptual explanations about informed consent related to each section of the document being read. We will also explore turning off the proactive phrase help trigger to determine the efficacy of requiring users to gaze at the agent when they need help.

Acknowledgements

We thank Kathleen Totzke and Teryn Falkingham for their help in conducting the study.

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