in press, 2007; Proceedings of the 51st Annual Conference of the Human Factors & Ergonomics Society

# An exploratory study of the effect of domain knowledge on internet search behavior: The case of diabetes

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This study investigated how domain knowledge, about diabetes, influences the process and outcome of answering complex questions using the internet. The internet has become an important source of knowledge for people seeking health information about diseases. People with chronic diseases often need a great deal of information for self-management and have emerging needs for new information. Participants in our exploratory study were 8 people with diabetes and 2 without. An initial interview identified individuals with high versus low knowledge about diabetes. We then traced the activity of individuals as they used the internet to answer questions about diabetes. Questions were designed to be difficult, require reasoning, and lack a single, integrated source with a packaged answer. Here we report on case analyses of one individual with high and one with low domain knowledge. Domain knowledge influenced activity in multiple respects, including initial orienting to the task and supplying facts needed in inference chains.

How do people use their existing knowledge to find new knowledge? People often pose and seek to answer questions based on their interests. Thus, they tend to seek information where they already have considerable knowledge, but need to know more. In the current study, we wanted to understand how existing knowledge guides the process of question answering. We sought a combination of users and topic where users had extensive knowledge available but wanted to know more. We investigated how they used the internet to fill these gaps.

In particular, we asked people to answer questions about diabetes. Effective treatment of diabetes depends on considerable patient knowledge of the medical condition to handle daily self-management tasks. After diagnosis, people with diabetes commonly take multi-session classes to learn about diabetes. We expected people with diabetes to be knowledgeable on the subject; and thus our first research question was what knowledge people with diabetes had about their medical condition.

Our preliminary interviews suggested that even people who have been diagnosed with diabetes for several years have self-identified additional knowledge they want. Examples included how the duration and the severity of diabetes affects the probability of disease complications; the effects of diabetes during pregnancy; and how diabetes affects cardiovascular health. Note that these questions are indeed complex and often cannot be answered by finding a single information source (e.g., website). Thus, our second research question was how people faced with complex questions would use knowledge about diabetes to guide finding additional information about diabetes on the web.

Prior studies suggest that domain-specific knowledge of the user, as well as general search expertise, influence how successful users answer questions and find information on the web. For example, in an economics domain, experts were more likely to look at a document returned by a search rather than refine a search, and only experts in both the domain and web searching ever began the task by

navigating directly to a content site (Hölscher & Strube, 2000). Novices in the medical domain seeking medical information have difficulties both because they lack medical terminology (McCray, Russell, Luane & Tse, 2004) and because they do not know the best sites for relevant information, in part because facts are widely distributed across pages (Bhavnani, 2005).

We think that an important part of question answering and information finding involves making sense of information (sensemaking), and that searching for or navigating to an answer is only one part of this sensemaking process. In many cases answering a question requires a progressive use of found information to deepen understanding, and to refine what additional information is needed. In contrast to this emphasis on sensemaking and understanding, prior research on the effects of expertise, and on web use more broadly, tend to focus on navigation, and treat answering a question mainly as a navigation problem. Whether by keyword searching, browsing, or the more flexible "orienteering" (Teevan et al 2004), the focus is on locating the right data: a fact that solves the fact-retrieval problem. Just as users differ in navigation methods, they also vary in strategies for making sense of the task and information (Billman & Bier, 2007). In the current study, we will document both the navigation and sensemaking strategies of people as they search for the answers to complex questions.

*Overview of the current study*: This was a preliminary study using a cognitive engineering rather than an experimental approach. That is, we used a small number of participants, recorded rich verbal and behavioral protocols, and analyzed data qualitatively. The overall study compared eight people with diabetes from a community sample to two people without diabetes. The latter sample is included as an informal control group, to allow us to see how high vs. low diabetes knowledge affects internet search for diabetes topics. Each participant completed: 1) an oral interview on their diabetes knowledge; and 2) two complex question answering and web search tasks related to diabetes. Data analysis in this paper focused on a detailed analysis and comparison of the navigation and sensemaking strategies of one participant with high diabetes knowledge and one with low diabetes knowledge as they answered the questions.

## Methods

### Participants

We used a community sample of eight people who had been diagnosed with Type 2 diabetes at least 6 months prior to the study, and a sample of two control participants without diabetes. The people with diabetes varied widely in education level and in computer and internet skill. All participants were required to have at least 12 months experience using computers and the internet.

### Tasks & Procedure

*Task analysis interview*. In an hour-long oral, tape-recorded interview, we asked questions regarding: general knowledge of diabetes; personal diabetes history; daily self-management activities and timeline; and handling emergencies. We initially expected that people with diabetes would have uniformly high diabetes knowledge, but knowledge about diabetes varied widely within this group. Thus, recruiting people with diabetes, even those who have had it for many years, is not a reliable way of getting people with comprehensive and high knowledge of the condition. (Some tentative findings from these interviews were that many of our participants were weakest in their knowledge of physiological mechanisms, and some participants tied their knowledge very closely to their own experiences.) In a similar vein, we found that recruiting people without diabetes is not a reliable way of getting people with low knowledge of diabetes. One of our participants without diabetes had a close relative with diabetes, and had learned a lot about diabetes from this person.

*Question answering tasks*. Following the task analysis interview, participants completed two complex question answering and web search tasks requiring some diabetes knowledge during a 30 minute session. The questions given to participants are shown in Table 1. Participants entered (i.e., copied or typed) answers into a word processing document open on a second monitor. Participants' verbal protocol and web search behavior were recorded.

Table 1. Questions used. Each question had three subparts. The italicized titles were not shown to users.

| |
|---|
| *Question 1: Blood sugar of 600 mg/dl*<br><br>A. What is the name of the medical condition where a person with diabetes has a blood sugar level of more than 600 mg/dl?<br>B. Name at least five symptoms of this medical condition.<br>C. Name at least two medical treatments for this condition. |
| *Question 2: Diabetes pill*<br><br>A. Pick one type of pill that is used to help people with diabetes reduce their blood sugar levels. Explain ***how*** this pill helps people with diabetes reduce their blood sugar levels.<br>B. Which type of diabetes does this pill work well for? Which type of diabetes does this pill ***not*** work well for?<br>C. If the pill does ***not*** work for one type of diabetes, explain ***why*** it does not work for this group. |

## Findings

The goal of this paper is to advance hypotheses about the strategies people use in knowledge-rich question answering and information search tasks, as well as hypotheses about how prior domain knowledge affects searching for answers. Therefore, we provide a rich descriptive analysis of how two participants – one with diabetes who had high diabetes knowledge and one without diabetes who had low diabetes knowledge – completed the two complex question answering tasks. Based on pilot testing, we suspected that peoples' web searching is affected not only by domain knowledge, but also by general question-answering skill (test taking skill) and general web search skill. The two participants whose data are presented here were chosen because they both had similar (and high) test-taking and web search skills (based on an informal assessment), but they differed in their diabetes knowledge. (Analysis of the diabetes task analysis interviews is important to understanding our research question, but is beyond the scope of this short paper.)

Table 2 shows the speed and accuracy of the two participants on the two question answering tasks. Although we cannot perform statistical comparisons of the speed and accuracy of the low- versus the high-knowledge participant, information about these participants' speed and accuracy is still important to a qualitative understanding of how domain knowledge affected their performance.

Table 2. Quantitative overview of performance of the two participants.

| | Parts Correct of 3 | Completion Time in min. |
|---|---|---|
| Low Knowledge | | |
| Question 1: 600 mg | 2 | 7.8 |
| Question 2: pill | 3 | 17.3 |
| High Knowledge | | |
| Question 1: 600 mg | 3 | 7.4 |
| Question 2: pill | 3 | 11.1 |

### Effects of diabetes knowledge on question answering

We first describe the question answering behavior of the participant without diabetes who had relatively *low diabetes knowledge*.

*Question 1 – 600 mg/dl condition.* Due to his lack of diabetes knowledge, this person initially spent time in familiarizing himself with the single diabetes website that he used, and in familiarizing himself with general information about diabetes by browsing within the site. The participant answered part C of this question (treatments) incorrectly because he did not know that a blood glucose level of 600 mg/dl is extremely high and requires emergency treatment. Thus, he made an incorrect inference that treatments for chronic effects of moderately high blood sugar in Type 2 diabetes would work for the acute effects of very high blood sugar in this problem.

*Question 2 – diabetes pill*. This person had considerable trouble answering part C (why does the pill not work for one type of diabetes) because he was answering the question for a pill that increased pancreatic insulin production and he did not know that Type 1 diabetics cannot produce any insulin. Based on his initial familiarization with diabetes, he had formed the incorrect conclusion that both Type 1 and Type 2 diabetics can produce some insulin but

have difficulty doing so; thus he reasoned incorrectly that the pill should work for both Types. Yet he found internet information that the pill only works for Type 2 diabetes. To resolve this contradiction, he set himself the subgoal of finding out how Type 1 diabetics deal with insulin. Setting the correct subgoal and finding the information relevant to this subgoal took a long time. This was the reason why this person took a long time on this task. However, once he found that Type 1 diabetics cannot produce any insulin, he answered part C correctly.

Below we describe the internet searching of a participant diagnosed with Type 2 diabetes 8 months prior to testing who had relatively *high diabetes knowledge*.

*Question 1 – 600 mg/dl condition*. In contrast to the person with low diabetes knowledge, this person spent no time familiarizing herself with diabetes websites or information. Also, this person did not have to set subgoals to fill in missing information about diabetes. Therefore, she worked directly from the question statement to finding related information on the internet, primarily using a strategy of search engine querying. This was accomplished accurately and quickly. One example of how this person used her prior knowledge of diabetes to guide her search occurred when she found a website with information related to the 600 mg/dl condition. This site referred to both moderate and severe hyperglycemia. From her prior knowledge, she knew that 600 mg/dl reflected severe, not moderate, hyperglycemia. So she used the term "severe hyperglycemia" to search for more information using a search engine.

*Question 2 – diabetes pill.* This person immediately used prior knowledge to answer the first half of part A (name a diabetes pill) without engaging in any web searching. She quickly searched for and found information to answer the second half of part A (how the pill works) and part B (what type of diabetes the pill does and does not work for). The correct answer to part C (why does this pill not work for one type of diabetes) is that any diabetes pill will not work well for Type 1 diabetes because pills cannot ameliorate the complete lack of bodily insulin production in Type 1; only insulin injections can do this. At the beginning of working on part C, the high-knowledge participant mentioned the key information that the participant with low diabetes knowledge lacked – that Type 1 diabetics cannot produce insulin. When she later found that the pill she was using worked by helping the body use its own insulin, she immediately combined this information with her prior knowledge that Type 1 diabetics cannot produce their own insulin, and was able to correctly answer part C. In a similar situation, the participant with low diabetes knowledge had to search for a long time to discover that Type 1 diabetics cannot produce insulin.

*Summary*. The picture emerging from these participants is that domain knowledge does affect how people answer questions using the web, as we found examples of knowledge effects during each of the four searches presented here. We identified a few examples of the kinds of diabetes knowledge that make a difference in how people answer questions. For example, how a person searches for information about how to treat a blood glucose level of 600 mg/dl depends on whether they know that this glucose level is very high  Also, a person's reasoning about why a diabetes pill will not work well for Type 1 diabetes is affected by whether the person knows that Type 1 diabetics cannot produce any insulin. In these examples, diabetes knowledge seems to be affecting search by providing specific chunks of knowledge that either are part of the answer or support bridging inferences to reach the answer.

**Description of participants' sensemaking and navigation strategies**

One commonality across these high-knowledge and low-knowledge participants was in their sensemaking activity. Both participants were actively attempting to understand the new information that they read during a search. For example, both attempted to integrate new information with prior knowledge (whether that prior knowledge was learned prior to or earlier in the test session), both noticed when newly found information conflicted with prior knowledge, and both combined new and old information in order to make inferences. However, the low-diabetes-knowledge participant employed a particular sensemaking strategy that was not needed by the high-diabetes-knowledge participant. At the beginning of his first search, the low-

knowledge person searched for a good general website on diabetes and then browsed this site in order to familiarize himself with diabetes.

We noticed the following navigation strategies in these protocols: using a global (i.e., internet-wide) search engine to search for a general website for the content domain; navigating to a known content-domain website (discovered either prior to or earlier in the session); focused browsing and querying within a single content-domain website; global search engine querying to look for problem-relevant information without much browsing.

At the level of specific strategies to access information, these participants used a similar set of strategies despite their knowledge differences. However, domain knowledge did influence search strategies, such as in the choice of specific search terms, or in choosing to visit a general domain site for content familiarization. We do not know whether the distribution of choices across navigation strategies or sites is influenced by prior knowledge, such as preference for a known favorite site.

## Conclusion

Based on a close examination of web search protocols for a few participants, we found evidence that participants' search for answers to complex questions is *knowledge driven* in two senses. First, participants regularly attempted to make sense of and reason about the information they encountered during search; that is, they attempted to turn information into knowledge. Second, participants regularly used their existing domain knowledge in this sensemaking process; but this meant that the participant with low domain knowledge had more difficulty in searching. This difficulty seemed to be evidenced in longer searches and inaccurate answers (although statistical support for this conclusion is lacking). In addition to documenting some of participants' sensemaking activities, this study identified some of participants' navigation strategies as they answered complex questions in knowledge-rich domains.

In further analyses of these data, we will characterize the structure and contents of participants' domain knowledge (as evidenced in the diabetes task analysis interviews). Then we will look for correlations between participants' domain knowledge and the sensemaking and navigation strategies they used.

## Acknowledgments

This project was funded by the Intelligent Systems Laboratory of the Palo Alto Research Laboratory, Palo Alto, CA and by the College of Business and Behavioral Science of Clemson University, Clemson, SC.

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