Developing A Dual-Process Information Seeking Model for Exploratory Search

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ABSTRACT
In this work dual-process theory from the social psychology domain is introduced to help understand exploratory search behaviors and relate them to searchers' cognitive processes as they evaluate information resources. Our setting is the consumer health domain, where information seeking is often an exploratory search episode involving searchers who have high motivation but low ability to find and cognitively process information resources. Health consumers learn as they search, acquiring information from professional and peer-produced resources. Interactions between user, interface, and content will be aggregated to form a model of exploratory search.

Keywords
Exploratory search, health informatics, dual-process theory

INTRODUCTION
This work investigates *exploratory search* [10] behaviors in the consumer health domain, where health consumers managing a chronic condition are likely to be highly motivated to find information resources and learn about a topic (their condition). However, searchers' abilities are largely constrained by their limited knowledge of both the information they need to satisfy their goals, and the resources that will best help them. *Dual-process theory* from the social psychology domain is used to frame exploratory search behaviors and relate them to cognitive processing of information resources. This research is intended to improve our understanding of exploratory search in Web search engines and health-related websites, develop a model of dual-process information seeking during Web searching and browsing, and inform future system development.

Exploratory searchers learn as they go, using acquired knowledge to evaluate new information encountered and guide future searches. Health consumers, at least at the start of an exploratory search episode (which may last hours, days, weeks, or more), are expected to have high motivation to search and learn, but relatively low ability due to the complexity of medical information and lack of system or domain knowledge. However, over time these patients can develop a level of expertise or wisdom about their condition [15] resulting in a greater ability to understand and process health information they encounter online – and thus changed information seeking behaviors.

Searchers are likely to process the panoply of resources returned in Web search engines through cognitive methods explained by dual-process theory from the social psychology domain; the *Elaboration Likelihood Model* (ELM) [12] and the *Heuristic Systematic Model* (HSM) [4]. These models, developed through years of experimentation, propose that humans cognitively analyze information in parallel via two concurrent processes. The first process, *central route* (ELM) or *systematic processing* (HSM) is cognitively intensive, requiring logical analysis of content and comparison of newly encountered information to previously held notions. The second process, *peripheral route* (ELM) or *heuristic processing* (HSM) is less cognitively demanding, relying instead on rules stored in memory, pre-existing ideas, and peripheral cues to influence analytical activity.

Dual-process theory is used to investigate health search behavior for several reasons; it has been little used in the information sciences to explore Web search and may offer new insights into evolving information seeking behaviors, it is widely used to guide research for public health communication campaigns (which are increasingly moving online), and it has influenced theories of trust and credibility for Web resources. Although developed primarily for persuasion research in the social psychology domain, the potential to provide insight on health consumers' information behaviors has been recognized [5]. We anticipate the ELM and HSM are practical for investigating the changing abilities and information behaviors that develop during exploratory search.

This paper describes a conceptual framework and proposed research investigating the relationship of dual-process theory and exploratory search. It aims to characterize information seeking behaviors building on previous work in information sciences, health informatics, and social psychology. Individual behaviors, happening at the "psychological" or "bounded rationality" time-scales (100 milliseconds to hours) of human action [11] will "percolate upward" [13:37] to form models of longer episodes. Examining health search behavior through the lens of dual-

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process theories should provide insight that can be leveraged to create future models, theory, and systems to support and enhance health searches.

CONCEPTUAL FRAMEWORK

Online Health Information

The Web is an important source of health information for a majority of US adults. Online health information often has a direct influence on health outcomes, including: decisions on how to treat an illness, patient-doctor communication, and managing pain or a chronic condition [7]. However, the complexity of health concepts and the sheer volume of online resources often make it difficult for a health consumer to find useful health resources, and understand what they find.

Health consumers are increasingly responsible for guiding their own healthcare process. The tenet that "physicians make recommendations but patients make the final decisions" is embedded in the *principle of patient autonomy*, proposed by the American Board of Internal Medicine and the European Federation of Internal Medicine [8:2]. The newly empowered patient requires intermediaries, be they human or machine, to find and understand information. Eysenbach's *apomediation* model [6] describes how health information consumers access information resources guided by search engines, webpages, and social media sites. The intermediary function, previously held by health professionals is now largely found in online information systems, particularly general search engines. These new intermediaries help health consumers navigate a complex and unfamiliar domain, with consumers making critical health decisions guided in part by resources provided in search user interfaces.

Figure 1. Sequence of moves in health information search.

Exploratory Search

Looking for health information online is often an exploratory search task where the information sought is ambiguous and unknown to the searcher. Exploratory search "blends querying and browsing strategies" that help a user "lookup, learn, and investigate" using parallel processes or tasks [10:42]. Exploratory searchers are generally: "(1) unfamiliar with the domain of their goal (i.e., need to learn about the topic in order to understand how to achieve their goal); (2) unsure about the ways to achieve their goals (either the technology or the process); and/or even (3) unsure about their goals" [14:10]. Health consumers starting a search are often unfamiliar with the medical topics they are researching, unaware of the resources and terminology needed to fully investigate their need, and not sure what information will satisfy their goal or even what there goals are. These searchers move through iterative collecting and gathering activities in sequence of moves, similar to Bate's berrypicking model [1], looking up facts, learning new concepts and developing expertise over time. Searchers may move between "evidence-based" to "hypothesis-based" information seeking modes [2], and their information needs and goals change over time due to the increased expertise due to the learning that occurs in exploratory search..

As the searcher discovers new knowledge, they gain expertise in the form of learned heuristics and increased ability to systematically process information that was previously inaccessible to them. Web searchers encounter health information from a wide variety of peer and professionally produced sources that they must process and evaluate. Increased ability in the domain can lead to changes in search behavior. Health information also has temporal and contextual facets. Information needs change as a health condition changes, such as pre and post-operative care requirements. Emerging research may be published, requiring the patient to revisit previously held beliefs. Different types of information can be relevant to a condition, like emotional or lifestyle support from fellow patients (i.e. how to select a wig for those losing hair in cancer treatment) that may have an impact on quality of life. A system that adapts to the user's evolving knowledge structures, abilities, and context can help enhance search performance and future learning. The present work aims to explore the cognitive components that influence these simultaneous search and learning processes by examining them through the lens of dual-process theory.

Dual-Process Theory

Dual-process theory was developed to characterize human judgment and information evaluation along two parallel tracks, heuristic processing or peripheral route, and systematic processing or central route. The two concurrent processing modes can help explain human evaluation and utilization of resources in an online information system. Using concurrent processes a human evaluates information resources based on its content (e.g. the text and informative images) and peripheral cues (e.g. design of the page, rank in a search results page, presence of advertising).

In this work, I use the Elaboration Likelihood Model of Persuasion [12] and Heuristic-Systematic Processing Model [4] to characterize exploratory search behaviors. These models assume that people want to hold attitudes that are correct, and want sufficient information to address their needs. A key component of dual-process theory is the *elaboration continuum* of the ELM that describes the impact of a person's motivation and ability on their elaboration, or cognitive effort. The ELM and HSM both hold that the human processor is constrained by motivation and ability to analyze information. As motivation and ability change, the searcher will move up or down the elaboration continuum with heuristic or systematic

processing taking predominate roles. Examples of ability include the person's health literacy level, system and domain expertise, and previous experience. External factors that can affect ability include time constraints and freedom from distraction. Motivational influences include severity of the health information need, desire for control and involvement in medical decision-making, and desire to learn. Searchers rely more on heuristic processing when either their ability or motivation are low, and more on systematic processing when they have both high ability and high motivation. As ability rises due to learning during exploratory search, systematic processing may become more prevalent, with heuristics becoming less important to the searcher.

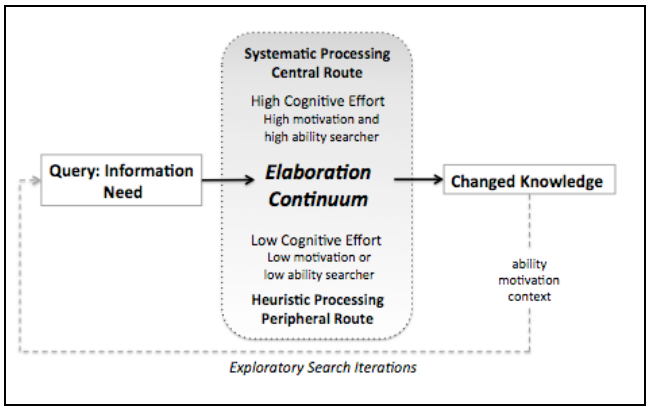

Figure 2. Dual-process theory in exploratory search.

Systematic Processing: The Central Route

Systematic processing is a "comprehensive, analytical orientation in which perceivers access and scrutinize all informational input for its relevance and importance to their judgment task, and integrate all useful information in forming their judgments" that requires "more than marginal levels of effort and cognitive capacity" [3]. When engaged in systematic processing, users exert substantial effort at cognitively processing information, and attempt to understand and evaluate the message in order to respond in a manner that advances their task goals. Information encountered is compared to previously held knowledge and attitudes developed through systematic processing are more stable than those developed through heuristic processing. Domain expertise provides greater ability to systematically process informative resources, thus learning is a key concept linking exploratory search and dual-process theory.

Heuristic Processing: The Peripheral Route

Heuristic processing is a "limited processing mode that demands much less cognitive effort and capacity than systematic processing" [3], that can be active when motivation or ability is low. Because the motivation is likely high for many health information searchers, and the ability low, it is expected that heuristics are a part of their information seeking behaviors. Examples of heuristic processing include *experts are usually correct*, *well-designed websites are credible,* and *the first result on a search results page is the best result*. Users store heuristics as knowledge structures, or decision rules, in their memory that help reduce cognitive load as they traverse an information domain. The searcher's heuristics may also change over time as they gain experience. For example early in an exploratory search "experts are correct" may only include medical doctors, while later that heuristic could be modified to include fellow patients who have managed a disease for a lengthy period of time. Successful use of heuristics requires their 1) availability – the user has stored them in memory, 2) accessibility – the user can retrieve the heuristic from memory, and 3) applicability – the relevancy of the heuristic to the present task [3].

RESEARCH QUESTIONS

The conceptual framework above led to the following research questions that will guide future investigation:

1) How are observed information seeking behaviors characterized as simultaneous heuristic and systematic processing?

2) What is the relationship of search stage (earlier to later iterations) to prevalence of heuristic and systematic processing?

3) What features of an interactive search system support enhanced exploratory search and learning by searchers engaged in dual-process information behaviors?

RESEARCH PLAN

The ideas proposed in this paper are as yet untested. They will be investigated in a two-part research project, conducted with participants who have ongoing health information needs. During part one, a diary based study, participants managing the chronic condition diabetes will be recruited from an education center or similar site. Patients who frequently search for health information will be selected for the study, in order to ensure we gather enough data to make useful characterizations about their information seeking over the course of the study. We will collect daily journal entries, and transaction logs if feasible, thus providing data that will allow us to characterize search behaviors over a period of time. Next, we will conduct an in-lab experiment to test a prototype search system with a design based on the characterizations developed from the data gathered in part one and behaviors described in the relevant literature. Unobtrusive screen-capture tools and browser plugins will capture interaction data and search tasks will be structured to elicit exploratory search needs.

Overall study design will be guided by previously reported experiments investigating dual-process theory, public health, and Web search. Key independent or quasi-independent variables reported in the literature include the characteristics of the participant's Web use and eHealth literacy, the search task, system, and context of the search. Questionnaires and subjective user reports like self-ratings, stimulated recall, and interviews can be used to measure cognitive effort and learning. Eye-tracking data can measure the participant's fixation on (and processing of) various interface elements. Data from different sources will

be triangulated to verify observations and strengthen conclusions. Relationships among variables will be used to build models of dual-process behaviors in exploratory search. For example, some factors may have higher influence than others during different search stages, and certain factors may mediate learning and processing while others moderate or limit learning and search performance.

DISCUSSION AND CONCLUSION

This research will feature observations of exploratory search behavior at a small scale – individual actions like a mouseclick or reading a webpage. These actions take place in the "psychological" and "bounded rationality" bands of Newell and Card's time scales of human action [11:226], ranging from 100 milliseconds (i.e. an eye fixation) up to hours (i.e. reading webpages). Individual actions will act as building blocks for the larger model [13] of exploratory search episodes lasting days or weeks, occupying the "social" band of human action. As individual actions on the psychological and bounded rationality bands change over time, they can provide evidence for predictive models of exploratory health search. It is expected that more heuristic processing will occur early in an exploratory search and more systematic processing in the later stages, although this assumption remains as of yet untested.

Marchionini wrote, "the aim of information seeking is to get relevant information into one's head and use it in conjunction with known information to take some action or integrate it into the knowledge base. This is accomplished by coordinating information-seeking factors in systematic and heuristic ways" [9]. This work uses the concepts of heuristic and systematic processing from dual-process theory as a way to gain insight into information seeking practices of users conducting exploratory health searches. A contribution will be to improve the understanding of changing search strategies and information evaluation methods as users with increasing ability interact with search tools (Google, Bing), peer-produced (forums, wikis), and professionally-produced information resources (MedlinePlus, MayoClinic) during a exploratory search episodes.

This research is intended to develop models and theory that contribute to the understanding of human information processing in exploratory search. The most common entry point to the vast wealth of information found online is search engines, making efforts to understand and improve use of these tools vitally important for the successful dissemination of health information. Health consumers can encounter conflicting or incorrect information online that has adverse influence on their ultimate health outcomes. Because search plays such a large role in health information [7], enhancing search engine technology is likely to have a large impact on improving learning and ability. Findings from this research should be useful for designers implementing interactive system features in Web search engines. Researchers may build on the findings to develop further studies that test future ideas in the health and other search domains. The ultimate goal of this work is to help health consumers find and understand the information needed to manage their conditions in order to attain healthier outcomes and increased quality of life.

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