Web Searching Interaction Model based on User Cognitive Styles

Khamsum Kinley, Dian Tjondronegoro and Helen Partridge
Faculty of Science and Technology, Queensland University of Technology
2 George St Brisbane, QLD 4000, Australia
{k.kinley, dian, h.partridge}@qut.edu.au

ABSTRACT

As more and more information is available on the Web finding quality and reliable information is becoming harder. To help solve this problem, Web search models need to incorporate users' cognitive styles. This paper reports the preliminary results from a user study exploring the relationships between Web users' searching behavior and their cognitive style. The data was collected using a questionnaire, Web search logs and think-aloud strategy. The preliminary findings reveal a number of cognitive factors, such as information searching processes, results evaluations and cognitive style, having an influence on users' Web searching behavior. Among these factors, the cognitive style of the user was observed to have a greater impact. Based on the key findings, a conceptual model of Web searching and cognitive styles is presented.

Author Keywords

Web searching, information seeking, information retrieval, cognitive style

ACM Classification Keywords

H.5.3 Web-based interaction; H.1.2 Human Factors

INTRODUCTION

The Web has become an important information source for many kinds of users. Students, professionals, academics and researchers search the Web daily to perform information retrieval (IR) tasks and to satisfy their information needs. However, with the rapid growth of information on the Web, users often find it difficult to locate relevant information.

Recent studies (Chen, Czerwinski and Macredie, 2000, Ford, Eaglestone, Madden and Whittle, 2009) have shown that individual differences have an impact on the Web users' searching behavior. Cognitive style is one of the most important individual differences in information behavior practice and research, as it affects the ways in which events and ideas are viewed and how an individual may think, react to, represent situations and make decisions (Riding and Rayner, 1998). Since user cognitive process provides an effective theoretical foundation for understanding human-computer

interactions (Gong and Zhang, 2005), it is vital to incorporate cognitive styles in Web search modeling.

Riding and Cheema (1991) grouped cognitive dimensions into two principal cognitive dimensions: the Wholist-Analytic (WA) and the Verbal-Imagery (VI) style dimensions. The *Wholist-Analytic* dimension of cognitive style describes the habitual way in which people think about, view and structure information in wholes or parts. This affects the way they learn and organize information. The V*erbal-Imagery* dimension of cognitive style describes an individual's tendency to process information either in verbal or verbal mode of representation and thinking. It refers to ways in which an individual would represent knowledge, in words (verbal) or mental pictures (images).

In this study, we define Web searching as a Web user's activities on Web search engines, such as information searching, while cognitive style is understood and defined as a user's approach to process, organize and retrieve information. A small but growing number of studies have begun to explore the relationship between Web searching and cognitive styles. However, no Web search model that fully incorporates users' cognitive styles has been developed.

RELATED STUDIES

Over the years a number of studies have explored and developed models that describe and explain different processes that individuals use for retrieving information from the Web, and have investigated many factors that influence these processes. Ford, Miller & Moss (2001) investigated the role of individual differences in Web-based searching. The study reported IR effectiveness linked to the Internet perceptions of lack of control over the Internet and that the Internet is too unstructured. They also found associations between poor retrieval and a verbaliser cognitive style.

Kim and Allen (2002) studied the impact of differences in users' cognition and search tasks on Web search activities and outcomes. The study findings reported strong task effects on search activities and outcomes; different tasks were associated with different levels of search activities and outcomes. Search characteristics, such as the use of specific search and navigation features, time spent in searching, number of sites viewed, and number of bookmarks created, were found to be influenced by an interaction between cognitive and task variables. For completing a task, searchers spent more time for the subject search task that requires the searchers to find

different pieces of information that are related to the subject given than for the known-item search task that requires the searcher to find a piece of information that is known to exist.

In 2005, Ford, Miller, & Moss reported links between low levels of Boolean searching and older individuals, and between analytic cognitive style and female gender; between high levels of Boolean searching and younger individuals, wholist cognitive styles and male gender.

The studies discussed above provide valuable insights into cognitive styles and Web searching research. These are the basis upon which this study is founded. However, limited empirical research exists that show interrelationships between Web searching and users' cognitive style. There is a need to examine implications of users' cognitive styles on their Web searching and to develop Web search models that incorporate users' cognitive styles.

RESEARCH AIMS

The main goal of this study is to enhance Web searching models with a greater understanding of how cognitive styles affect Web searching. The study examines user Web interactions, implications of users' cognitive style on their Web search, and develop a conceptual model that illustrates the relationships between users' Web searching and their cognitive styles.

RESEARCH DESIGN

Data Collection

Four postgraduate students participated in the study. Demographic information, including prior search experience, were collected by using a questionnaire. Cognitive style was determined by Riding's (1991) Cognitive Style Analysis (CSA) test. The CSA is a computer presented test to measure the wholist-analytic and verbal-imagery dimensions of cognitive styles. Although there has been a few studies questioning its reliability and validity (Peterson, Deary and Austin, 2007), Riding's CSA test was chosen based on the following points:

- CSA test is relatively new compared to any other cognitive style test;

- A good number of studies have used CSA test (examples includes: Ford, Eaglestone, Madden and Whittle, 2009);

- CSA assesses both ends of the style dimensions i.e., wholist-analytic and verbal-imager cognitive style dimensions; and

- CSA test is a computer administered test which often makes it more attractive to participants.

The CSA test indicates the position of an individual on each of the fundamental style dimensions by means of a ratio. Participants scoring below 1.20 on the wholist-analytic scale were classified as wholist, and those scoring 1.20 or above as analytic. Similarly, participants scoring below 1.03 on the verbal-imager scale were classified as verbaliser and those scoring 1.03 or above as imager. Based on their WA and VI scores, participants

ParticipantID	WA Ratios	VI Ratios	Cognitive Styles
Participant1	1.07	1.12	Wholist-Imager
Participant2	2.21	1.03	Analytic-Imager
Participant3	0.71	1.33	Wholist-Imager
Participant4	2.02	0.93	Analytic-Verbaliser

Table 1: WA and VI Ratios and Cognitive Styles

were categorized as wholist-imager, analytic-verbaliser or analytic-imager. Table 1 provides an overview of the participants' cognitive style.

The data about users' computer interactions were collected using think-aloud and Web search logs, which were recorded using a monitoring program. Factors, such as users' cognitive styles which affect Web search interactions, were considered as *independent variables,* while, Web search actions or indicators that get affected, such as the number of search terms, were identified as *dependent variables*.

Independent Variables

User's Cognitive Style: The cognitive style of the participant: Wholist-Verbaliser, Wholist-Imager, Analytic-Verbaliser and Analytic-Imager.

Domain Search Experience: The level of search experience in terms of number of years.

Dependent Variables

Terms: The number of search terms submitted to accomplish a search task.

Query: The number of queries submitted to complete assigned tasks successfully.

Navigation node: The sum of number of URL links visited and navigational buttons clicked (back button, home button, forward button, history list, and stop button).

Interactive Feedback: The number of interactive feedback cycle occurrences, which involves the user's evaluations of IR system output, user's judgments and query modifications.

Session duration: The total time taken by a user to complete assigned tasks successfully.

Search Tasks

Once the CSA test and survey questionnaire were completed, the participants were assigned with three search tasks to complete using any search approach.

Task 1: Imagine you want to learn about the Web 2.0 platform but have no previous knowledge or experience. Find suitable materials on the Web for people with no experience.

Task 2: You have decided to conduct a research using grounded theory approach. Find relevant information on grounded theory and its benefit in a qualitative research.

Task 3: Answer the following question as quickly as possible. A technician is badly injured while performing her duty in an Australian university. What are the legal implications of this for the university?

The search tasks were designed with different levels of difficulty and complexity, and a diverse area of topics. Task 1 presented the least complexity in that the participants were asked to find any suitable materials on the Web 2.0, which required using basic searching skills. Task 2 was of more complexity and required a higher level of search experience. Task 3 was more complex compared to Task 2 and required participants to use a more advanced level of search terms and retrieve the information as quickly as possible.

Data Analysis
The independent variables were identified through analysis of the CSA test and questionnaire. The recorded screenshots and audios were replayed several times to create participant observation memos with search logs, session length, and think-aloud stamps; each participant's exact key strokes, websites visited, time spent and verbalized text for each assigned search task, were transcribed carefully and recorded in a sheet. Table 2 illustrates an example of the transcripts and Web logs developed.

Time	Search URL	Think-aloud	Researcher's remarks
1300	Web 2.0 platform general purposes	"What is this?"	This was the first time the participant opened a page in a new tab

Table 2: Transcribed Data: An example of Web logs format

In order to measure each dependent variable, each participant's memos were then analyzed using elements of content analysis (Julien, 1996) within a constructivist grounded theory approach (Charmaz, 2006).

RESULTS

The Query Modification Strategies
This study provided valuable insights into Web query reformulations. The results confirm other studies (Jansen, Booth and Spink, 2009) that Web users frequently make changes to their previous search query in order to improve the results of the search.

The Web users exhibited a high level of query modification strategies; some users used top-down query modification strategies (Participant 1 and 3), bottom-up query modifications (Participant 4) whilst others used mixed strategies (Participant 2). Top-down is a strategy where users search on a general area and then narrow down their search until they find the information needed (Navarro-Prieto, Scaife and Rogers, 1999). In contrast, bottom-up strategy users look for specific keywords in the search engine and then scroll down the results until they find the required information.

Further, Participant 3 was found using synonyms for 'implications' to retrieve information. He believed that using synonyms would help him in finding the required information. Participant 3 also used the 'define' keyword to retrieve definition of the word under review. Google

define: keyword search is a quicker way of finding word meaning and definitions using Google search engine.

Cognitive Styles
A good number of cognitive factors, such as information needs, information searching process, results evaluations, information search efficiency, level of Web search experience and cognitive styles, were found to have an effect on a Web user's search behavior. Among these factors, the *cognitive style* of a user was observed to have a greater influence.

Analytic-imagers were characterized by phrase-oriented searching as they tended to either add or reduce sub-phrases during their query modifications. On the other hand, wholist-imagers were distinguished by word-oriented searching. They tended to modify their queries by replacing parts of the search terms with new words. Web users' *prior domain knowledge* and *search experience* have also been found having effects on their Web search behavior, as seen in case of Participant 4; the think-aloud protocol analysis confirmed the user struggling to complete Task 1 because he did not have background knowledge on the Web 2.0.

Relationships between Users' Web Searching and Their Cognitive Style
The results from this study confirm the hypothesis that there is a significant relation between Web search behavior and user cognitive styles. Wholist-imagers and analytic-imagers relatively completed a greater number of feedback cycles as compared to analytic-verbalisers. Knight and Spink (2008) reported that system feedback can be referred to as the user's search tactics, which indicates that imagers were relatively more search expert compared to verbalisers.

A closer analysis of Web search logs and think-aloud protocol revealed that during the search interactions, analytic-imagers (Participant 2) tended to move back and forward more frequently than the rest. Researchers suggest that such frequent use of navigation buttons can be viewed as an indication of "getting lost" (Kim, 2000). If this is the interpretation, then analytic-imagers tended to get lost while performing Web searching. However, Riding (1998, p. 28) reported analytic-imagers as a "hesitant in making decisions" but "idealistic" and follow "a set of principles", which is contrasting with that of Kim's (2000) interpretation. An in-depth study, with a larger sample size, is required to investigate, compare and confirm the previous findings.

DISCUSSIONS
Based on the key findings of the study, a preliminary conceptual model of cognitive style and Web searching is presented (see Figure 1). The model presents the relationships between different components of Web searching and cognitive styles; includes five main components: information needs, the user, cognitive style domain, Web searching and information retrieval.

The *information need* of a user influences the user's information seeking behavior (Wilson, 1981). *The user*

interacts with search engines and engages in Web searching in order to retrieve information and be satisfied with the information need. The user is placed in the centre of the model to indicate the importance of a user in information retrieval. A series of actions take place around the user during user- Web interactions, which are affected by the user's *cognitive style domain*. The efficiency and completion of a user's task depends on how he or she coordinates and processes mental information. During *Web searching*, the user with the information need and the specific cognitive style, formulates queries, executes searches and examines query results to make judgments regarding the system and the relevancy of the content to meet their information need. The user then moves to the *information retrieval* stage. If the user is unable to retrieve the information needed, he or she may initiate a complete searching process again or even revisit the information need and the search task topics. This action loops in a cycle unless terminated as the result of successful IR, or user opt to cease or IR system termination due to a failure.
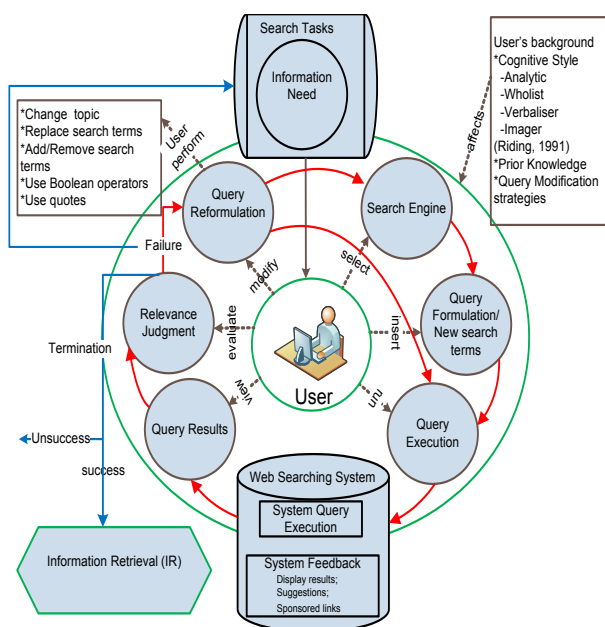
Figure 1: Preliminary Model of Web Searching and Cognitive Styles

CONCLUSION AND FUTURE WORK

The conceptual model, presented in this study, provided valuable insights into user-Web interactions and confirmed the validity of the hypothesis that there is a significant relationship between Web search behavior and cognitive styles. However, the study findings are indicative and the preliminary model presented is in its infancy as the findings are based on a small scale population sample. A study with a larger population sample, between 50 and 60 participants, is in process and its findings will be reported in future papers.

REFERENCES

Charmaz, K. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. Sage Publications Ltd, (2006).

Chen, C., Czerwinski, M. and Macredie, R. Individual Differences in Virtual Environments - Introduction and Overview. *Journal of the American Society for Information Science*, 51, 6 (2000), 499-507.

Ford, N., Eaglestone, B., Madden, A. and Whittle, M. Web Searching by the "general public": An Individual Differences Perspective. *Journal of Documentation*, 65, 4 (2009), 632-667.

Ford, N., Miller, D. and Moss, N. The Role of Individual Differences in Internet Searching: An Empirical Study. *Journal of the American Society for Information Science and Technology*, 52, 12 (2001), 1049–1066.

Ford, N., Miller, D. and Moss, N. Web Search Strategies and Human Individual Differences: Cognitive and Demographic Factors, Internet Attitudes, and Approaches. *Journal of the American Society for Information Science and Technology*, 56, 7 (2005), 741-756.

Gong, Y. and Zhang, J. A Human-Centered Design and Evaluation Framework for Information Search. In Proc. the AMIA Symposium, (2005), 281-285.

Jansen, B., Booth, D. and Spink, A. Predicting Query Reformulation During Web Searching. In Proc. 27th international conference extended abstracts on Human factors in computing systems, ACM (2009), 3907-3912.

Julien, H. A Content Analysis of the Recent Information Needs and Uses Literature. *Library & Information Science Research*, 18, 1 (1996), 53-65.

Kim, K.-S. Users, Tasks, and the Web: Their Impact on Information Seeking Behavior. In Proc. 21st Annual National Online Meeting, (2000), 189-198.

Kim, K.-S. and Allen, B. Cognitive and Task Influences on Web Searching Behavior. *Journal of the American Society for Information Science and Technology*, 53, 2 (2002), 109-119.

Knight, S. L. and Spink, A. Toward a Web Search Information Behavior Model. In A. Spink and M. Zimmer (Eds.), Web Searching: Interdisciplinary Perspectives. Springer (2008), 209-234.

Navarro-Prieto, R., Scaife, M. and Rogers, Y. Cognitive Strategies in Web Searching. In Proc. 5th Conference on Human Factors & the Web, (1999).

Peterson, E. R., Deary, I. J. and Austin, E. J. Celebrating a common finding: Riding's CSA test is unreliable. *Personality and individual differences*, 43, 8 (2007), 2309-2312.

Riding, R. *Cognitive Styles Analysis*. Learning and Training Technology, Birmingham, (1991).

Riding, R. *Cognitive Styles Analysis -Management Style and Team Working*. Learning and Training Technology, Birmingham, (1998).

Riding, R. and Cheema, I. Cognitive Styles—An Overview and Integration. *Educational Psychology*, 11, 3 (1991), 193-215.

Riding, R. and Rayner, S. *Cognitive Styles and Learning Strategies: Understanding Style Differences in Learning and Behaviour*. David Fulton, London, UK, (1998).

Wilson, T. D. On User Studies and Information Needs. *Journal of Documentation*, 37, 1 (1981), 3-15.