Toward a Web Search Model: Integrating Multitasking, Cognitive Coordination, and Cognitive Shifts

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Limited research has investigated the role of multitasking, cognitive coordination, and cognitive shifts during web search. Understanding these three behaviors is crucial to web search model development. This study aims to explore characteristics of multitasking behavior, types of cognitive shifts, and levels of cognitive coordination as well as the relationship between them during web search. Data collection included pre- and postquestionnaires, think-aloud protocols, web search logs, observations, and interviews with 42 graduate students who conducted 315 web search sessions with 221 information problems. Results show that web search is a dynamic interaction including the ordering of multiple information problems and the generation of evolving information problems, including task switching, multitasking, explicit task and implicit mental coordination, and cognitive shifting. Findings show that explicit task-level coordination is closely linked to multitasking, and implicit cognitive-level coordination is related to the task-coordination process; including information problem development and task switching. Coordination mechanisms directly result in cognitive state shifts in information problem understanding and knowledge contribution. A web search model integrating multitasking, cognitive coordination, and cognitive shifts (MCC model) is presented. Implications and further research also are discussed.

Introduction

Web search is now the predominant channel for many people to acquire information. People interact with web search systems, incorporating both behavioral and cognitive aspects such as constructing search strategies, formulating queries, and judging the relevance of information retrieved (Du & Spink, 2008). Previous studies have modeled some aspects of web search, such as examining dynamic interactions between people, their information problems (IPs) and the World Wide Web (WWW), web search task characteristics, intent and individual differences, and search strategies, processes, and outcomes (Ford, Miller, & Moss, 2001, 2005; Wang, Hawk, & Tenopir, 2000; Xie, 2000).

Recent research has shown that users engage in multitasking information behavior during web search (Ozmutlu, Ozmutlu, & Spink, 2003; Spink, Ozmutlu, & Ozmutlu, 2002; Spink, Park, Jansen, & Pedersen, 2006). Multitasking and task switching are important web search behaviors (Spink & Park, 2005; Spink, Park, & Koshman, 2006). Web search is seen as a multitasking process that often includes switching between multiple topics within single or multiple web search sessions. Successive searches embedded in multiple search sessions are common during web searching (Spink & Park, 2005). Multiple information-seeking episodes include successive web searches that are cognitively constructive as searchers learn with information attainment along the course of multiple-episode searches (Lin, 2005).

People also cognitively construct web searches, for example, by allocating cognitive resources among multiple tasks and shifting in cognitive, problem, and knowledge states (Du & Spink, 2008, 2009). Multitasking includes cognitive shifts in task focus. Web search includes many shifts in cognition at different levels in terms of IP and personal knowledge (Du & Spink, 2009; Robins, 2000; Spink, 2002; Spink & Dee, 2007). Cognitive shifts are due to humans’ high-level mental processing in response to external stimuli (Simon, 1981). Modeling the nature and types of cognitive shifts during web search is crucial to the development of web search models.

Web search also includes cognitive coordination. Wickens and Gopher (1977) argued that people consciously trade off performing one task for another due to their coordination
capability. Cognitive coordination at different levels enables humans to manage various dependencies among tasks and resources available (Miyata & Norman, 1986). Coordination mechanisms enable people to construct and manage search tasks and web resources. People may cognitively coordinate a number of elements, both internal (cognitive) and external (environmental), to achieve a coherent web search process (Du & Spink, 2008). Further study is needed to understand what elements are cognitively coordinated at different levels and how these elements interplay during web search.

In summary, existing studies have explored some aspects of multitasking, cognitive shifts, and cognitive coordination. The study reported in this article investigates the nature of cognitive coordination and its impact on various shifts in cognition and multitasking searching behavior in the web search context. The results of this study are significant for a deeper understanding of web search to extend web search models by integrating multitasking and the underlying cognitive and coordination support mechanisms, and have implications for improving the design of search systems and interfaces facilitating user–web interaction.

Related Studies

Web Search Models

Web search models show peoples’ interactions with web search systems, including search patterns, sequences, and search strategies (Catledge & Pitkow, 1995; Hawk & Wang, 1999; Montgomery & Faloutsos, 2001; Rieh & Xie, 2006; Tauscher & Greenberg, 1997). Choo, Detlor, and Turnbull’s (2000) web search model depicts how people translate their information needs into search strategies, their motivations (i.e., the strategies and reasons for viewing and searching) and moves (i.e., the tactics used to find and use information). Wang et al. (2000) viewed web search as a communication process facilitated through an interface. They analyzed web search behavior including question analysis, search strategies, and cognitive style. While pointing to the importance of users’ mental models in the provision of information, their model does not elaborate in detail on users’ cognitive efforts. Ford et al. (2001, 2005) identified key individual differences such as cognitive styles, study approaches, prior experience, perceptions, gender, and age, which were factors linked to web search strategies and performance.

Previous web search models have identified web search strategies and described factors affecting web search; however, few of them have examined the dynamic cognitive changes which occur during web search and the impact of these changes on web search strategies. In addition, few web search models include multitasking. Current web search models are generally based on the assumption that users are engaging in a single web search session on a single topic. Yet, an increasing number of recent studies have demonstrated that people engage in multiple web search sessions on multiple topics.

Multitasking

Multitasking is a fundamental concept in cognitive sciences and psychology. Multitasking refers to humans’ ability to concurrently or sequentially handle the demands of multiple tasks through task switching (Burgess, 2000; Carlson & Sohn, 2000; Lee & Taatgen, 2002). Humans switch from one task to another in a rapid succession during multitasking (Monsell, 2003; Wickens, 1991). The performance of multitasking and task switching, including the selection, initiation, execution, and termination of each task, are governed by cognitive executive control systems which provide a supervisory function controlling perceptual, motor, and cognitive processes (Rubinstein, Meyer, & Evans, 2001).

Within interactive information retrieval (IR) and web search, multitasking is understood as searches across multiple topics during single or multiple search sessions (Spink, Ozmutlu, & Ozmutlu, 2002). Multitasking has been analyzed based on the web search logs of several web search engines. For example, Ozmutlu et al. (2003) found that one tenth of Excite users and one third of AlltheWeb.com users conducted multiple-topic searches within a certain session. Koshman, Spink, and Jansen (2006) reported that 11.1% of search sessions over the Vivisimo search engine included a broad variety of search topics. Spink, Park, Jansen, and Pedersen (2006) found that a high degree of multiple topics exist in both two-query sessions (81%) and three or more query sessions (91%) on the AltaVista search engine. Multitasking has been observed as an important attribute of web searching behavior.

Spink, Park, and Koshman (2006) investigated how multiple IPs were ordered when users engaged in web search. The factors affecting the ordering of multiple IPs include: personal interest, problem knowledge, perceived level of information available on the WWW, ease of finding information, and level of importance. However, multitasking is still a somewhat primitive concept in web search research. Previous investigations focus on multiple search topics and ordering between the topics. Web search models have paid little attention to exploring the cognitive aspects of multitasking and models of multitasking in the web search context.

Du and Spink (2009) found multitasking to be more complex than previously portrayed in web search models. Multitasking is strategically controlled by cognitive executive processes which enable humans to choose and prioritize tasks, and monitor, interrupt, and adjust task performance (Glass, 1996; Rubinstein et al., 2001). Studies are needed to explore how such cognitive control processes allocate resources and establish priorities among multiple tasks, thus enabling efficient multitasking during web search.

Coordination

Coordination is the process of managing dependencies among activities or conflicts between goals, tasks, and resources of various agents (Crowston, 1997; Kling et al., 2001; Rapoport & Fuller, 1998). Coordination concept
complexity is reflected in the disciplinary differences in its understanding, for example, supply chain coordination in business, force coordination in health and exercise sciences, communication coordination in natural language, and cognitive architecture and control hierarchy in psychology (Clark, 1996; Freitas, Krishnan, & Jaric, 2007; Phillips & Silverstein, 2003; Sarmah, Acharya, & Goyal, 2007) all express variations on coordination. In IR models, coordination also is understood as modulation among subsystems, including planning, agenda, user modeling, request modeling, and input/output requests (Belkin, Brooks, & Daniels, 1987).

Ma’s (2008) interactive IR coordination model views coordination as an intrinsic and fundamental process of IR interaction that occurs similarly to a communication process in natural language. Interactive IR is described as a process of coordination involving the dynamic identification and construction of common ground between the user and the IR system. The common ground consists of a good knowledge of the matching mechanism, of requests, search strategies, and tactics, and of the search objectives. The concept of coordination within the interactive IR model has begun to evolve.

Park’s (2008) model incorporates individuals’ coordination between their internal (i.e., cognition, emotion, effort, and time) and external (i.e., task performance) activities through continuous self-feedback. However, Park’s model does not fully account for the nature and role of cognitive coordination during web search. Psychologists Miyata and Norman (1986) believed that humans have different levels of cognitive coordination to manage various dependencies. To achieve a coherent web search process, people cognitively coordinate a number of dependencies or factors, including their cognitive state, their level of domain knowledge, and their understanding of IPs (Du & Spink, 2008, 2009).

Cognitive Shifts

Cognitive shifting is a psychological phenomenon experienced by individuals. Cognitive shifting is a higher mental process because it relies on interaction between the brain’s internal mechanisms and external forces (Simon, 1981). Xie (2000) identified three levels of shifts in users’ attempts to achieve searching goals: current search goal shifts, interactive intention shifts, and search strategy shifts. Robins (2000) discussed shifts in focus of the conversation between a user and a search intermediary with respect to the user’s IP. Shifting of focus was denoted by a change in some topical aspect of the conversation or by some shift to a nontopical aspect of the IP.

Santon (2003) investigated users’ cognitive shifts between different search stages in an iterative IR process. Users may experience some type of shift in IP processing, in cognitive, problem, and knowledge states (Du & Spink, 2009; Spink, 2002; Spink & Dee, 2007). However, cognitive research has largely been confined to consideration of users’ postinteraction cognitive shifts, with little empirical investigation of the types and frequency of shifts in cognition during user–Web interactions (Ingwersen & Järvelin, 2005). Limited studies have investigated the occurrence and nature of undergoing cognitive changes as users search on the Web.

Conceptual Framework

Based on the review of literature, a preliminary theoretical model (Figure 1) was developed to present a proposed relationship between multitasking, cognitive coordination and cognitive shifts during web search.

This model shows that user–WWW interaction occurs in the context of information searching problems, cognitive processes of the user, and environmental factors relating to the information. These factors work together to assist users as they respond to the search process and search results, and develop understanding of their IPs and knowledge. Web search includes multitasking and task switching processes, and coordination of cognitive resources among several tasks along with the occurrence of cognitive shifts in users’ mental responses. Cognitive coordination allows humans to manage dependencies among internal and external factors under cognitive executive control. Cognitive coordination can be considered as a central process of web search that is taking place between users’ physical multitasking behavior and cognitive shifts (as shown in the dotted-arrow line).

A key issue for cognitive coordination research in the Web search context concerns the coordination mechanisms that move users through a multitasking web search along with various shifts in cognition. Cognitive coordination, in conjunction with multitasking and cognitive shifts, may form a theoretical framework for understanding how web search is constructed. This initial model is to be refined through the empirical work in the study.

Research Questions

The major research question examined in this study is: What is the relationship between multitasking, cognitive coordination, and cognitive shifts during web search?

The following three specific research questions are addressed in this study:

- **RQ1**: How do users conduct web searches on multiple IPs?
- **RQ2**: What levels of cognitive coordination occur during web search?
- **RQ3**: What types of cognitive shifts occur during web search?

Research Design

Data Collection

Participants. Participants were 42 graduate students from the Queensland University of Technology (QUT) in Brisbane, Australia, during September and November 2008 (Table 1).

Participants were recruited via e-mail groups under the guidelines of the QUT Research Ethics Committee. Ninety
FIG. 1. A preliminary theoretical model of multitasking, cognitive coordination, and cognitive shifts during web search.

<table>
<thead>
<tr>
<th>TABLE 1. Summary of study participants’ profile.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Current level of study</td>
</tr>
<tr>
<td>Disciplines</td>
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<tr>
<td>Web use experience</td>
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</table>

percent of the participants were doctoral and masters’ students between the age of 20 and 39 years (24 males and 18 females) from diverse disciplinary programs. Some 88% had web searched for over 6 years.

**Information searching problems.** IPs are the underlying motivation for information seeking and retrieval (Ingwersen & Järvelin, 2005). An information searching problem provides a context which implies a broader range of factors affecting the searching process, such as query formulation, relevance judgments, and information searching and use behavior (Robins, 2000). To better simulate Web search reality, the information searching problems were solicited from users’ real work and life rather than imposed by the researcher. To investigate multitasking behavior, participants were asked to prepare for three IPs and to bring them to the study session. Participants worked on their own IPs (original IPs [OIP], see Table 2, second column) when conducting web search for this study.

The 126 OIPs (3 IPs per participant × 42 participants) across 15 different topic areas were related to thesis research (45%), assignments (12%), jobs (11%), travel (8%), news (4%), food (3%), technology (3%), finance (2%), lifestyle (2%), music and movies (2%), online shopping (2%), sports (2%), answers (1%), online gaming (1%), and housing rentals (1%). Over two thirds of the participants conducted the Web searches on three unrelated IPs.

**Web search systems.** There was no treatment or control on how the participants interacted with the Web to find solutions to their IPs. Participants were free to use their preferred search systems to start the searching and to continue the process. The employed search systems ranged from Web search engines (e.g., Google, Google Scholar, Yahoo!, Live Search, CiteSeer, and Baidu) and professional databases (via QUT Online Library, e.g., Science Direct, Engineering Village, EBSCO, ProQuest, Wiley InterScience, and IEEE Xplore) to various websites with searching features (e.g., bank websites, airline websites, etc.).
<table>
<thead>
<tr>
<th>Participant</th>
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<th>Evolving Information Problem (EIP)</th>
<th>No. of Information Problems (OIP + EIP)</th>
</tr>
</thead>
</table>
| 1           | OIP1. Looking for the real cases of countermeasures to counter economic espionage internationally.  
OIP2. Looking for the real cases of crimes committed by people who have been previously convicted and later released or paroled from prison.  
OIP3. Looking for the real cases of any ferry boats sinking around the world. | None | 3 |
| 2           | OIP1. Information on analogy relations between evaporative cooling and cooling tower.  
OIP2. Looking for different applications of evaporative cooling: cool water or air.  
OIP3. Looking for the issues on evaporative cooling of air. | None | 3 |
| 3           | OIP1. Looking for a cheap bicycle, brand new or secondhand.  
OIP2. Looking for the literature about traveler’s route-choice behavior on urban public transit network.  
OIP3. Looking for the latest news about China’s spaceship “Shenzhou-7;” in particular, about the astronauts’ food. | EIP1. Looking for the Website URL of “eBay.” | 4 |
| 4           | OIP1. Information relating to Marxian appropriation: contemporary use and current theories applying this perspective (keywords: natural, species, & social being).  
OIP2. Looking for a foreign film I saw on SBS.  
OIP3. Information on coming releases in industrial and EBM (Electronic Body Music) music. | None | 3 |
| 5           | OIP1. Looking for the companies with 20–30 people only in Brisbane CBD.  
OIP2. Looking for the journalists of media outlets on health & fitness.  
OIP3. Looking for Formula 1 game websites (play online). | EIP1. Looking for the website URL of “EA Sports.”  
EIP2. Looking for the website URL of “Microsoft Games.”  
EIP3. Information on names of gaming companies.  
EIP4. Looking for the website URL of “MSN answers.”  
EIP5. Looking for the website URL of “a CBD building.”  
EIP6. Looking for the website URL of “another building.”  
EIP7. Looking for the website URL of “another building.”  
EIP8. Looking for the website URL of “another CBD building.” | 11 |
| 6           | OIP1. Information on multichannel video content delivery.  
OIP2. Information on how to transmit video data in the network environment.  
OIP3. Looking for the present methodology in video transcoding. | None | 3 |
| 7           | OIP1. Looking for the calculation methods for trip generation rates, person trips, or vehicle trips, for Transit Oriented Developments (TODs).  
OIP2. Information on travel behaviors of people living using a TOD: mode choice, trip length, walking trips, intrazonal trips, etc.  
OIP3. Information on statistical analysis of travel data including demographic, socioeconomic, and travel/trip details (e.g., the relation between mode choice and age of person). | None | 3 |
| 8           | OIP1. Information on the effect of passengers crowding at bus stop/station on the dwelling time(s) of buses.  
OIP2. Information on the current practice of road pricing (Toll Road) around the world.  
OIP3. Looking for different day tours available in Malaysia; tour operators (guides) and cost involved. | EIP1. Information on the transit visa in Malaysia.  
EIP2. Looking for the differences between revenue generation and travel demand management. | 5 |
<p>| OIP1 | Looking for the potential of finding a good job in statistics in Australia and the rest of the world. |
| OIP2 | Information on the effects of U.S. financial crisis on Australian job market and economy in many ways in future and what I should do to protect myself. |
| OIP3 | Looking for the scholarships for postgraduate research students in Australian universities. |
| OIP1 | Information on how the great chain of being has manifested over the millennia. |
| OIP2 | Information on the link between food and education: sociocultural explanations of the role of food in education. |
| OIP3 | Information on septennial taxonomy of everything: seven planes describe/repeat all things known and unknown in the universe, and the relationship between what we know of these seven planes. |
| OIP1 | Looking for the cheapest ticket to New Zealand during summer vacation. |
| OIP2 | Looking for the activities I can do in New Zealand. |
| OIP3 | Information on advertising issue of fashion industry (e.g., using female body to sell products such as clothes, watch, and perfume). |
| OIP1 | Looking for the cheapest yet most wide-travelling route of car hire and travel from Atlanta to Las Vegas. |
| OIP2 | Looking for the names of the schools or agencies that will offer a summer school camp in South Korea. I would like to teach English near Seoul and be there for more than 1 week. |
| OIP3 | Looking for brief accounts of overseas peoples’ reclamation of sacred sites and Australian cases, indigenous land and sea rights and protection of traditions in Australia. |
| OIP1 | Looking for general information on asset management and specific area such as public asset management: how the government in developed and developing countries manage their public asset, and whether there is any best practice or guidelines, etc. |
| OIP2 | Information on how local government is being structured in Australia, Queensland and in Brisbane, and the comparison with Indonesian local government’s structure. |
| OIP3 | Information on the definition of public policy and the factors affecting the policy maker when making a particular policy and the process of public policy making. |
| OIP1 | Information on Chinese consumers’ mobile phone adoption behaviors: How they respond to new mobile technologies, and What factors affect their adoption behaviors? |
| OIP2 | Looking for the status quo of 3G technology in China market. |
| OIP3 | Looking for the differences of consumer behaviors toward new innovation between two China regional markets: North market and East market. |
| OIP1 | Looking for the 10 schools, private or state, in radius 30 minutes’ drive from my house (Eight Mile Plains). |
| OIP2 | Looking for caravan parks around Melbourne and those are on the way to Melbourne: name and price. |
| OIP3 | Looking for the cheapest accommodation and flight to New Zealand on the mid of January, for 2 weeks. |
| EIP1 | Information on the job salary as a statistician. |
| EIP2 | Looking for scholarships for international students in Australia. |
| EIP3 | Looking for some news headlines about U.S. financial crisis. |
| EIP4 | Information on how to become an actuary. |
| EIP5 | Information on how to become a statistician. |
| EIP1 | Looking for the cheapest ticket from Brisbane to Auckland. |
| EIP2 | Looking for the website URL of “Jetstar.” |
| EIP3 | Looking for the cheapest ticket from Brisbane to Christchurch. |
| EIP4 | Information on how the hired car can be returned in the United States. |
| EIP1 | Information on the definition of concepts: local and municipal. |
| EIP2 | Looking for the local government structure in Canada. |
| EIP3 | Looking for the local government structure in Malaysia. |
| EIP4 | Looking for the website URL of “Yahoo Scholar.” |</p>
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| 16         | OIP1. Looking for some program examples written in JAVA and read in XML files from an RSS feed & display in a swing GUI (RSS News Aggregator-JAVA Based).  
OIP2. Looking for racing statistics of Easy Rocking Filly (female baby horse, 2 years old): what distances this race horse will be best suited to run over.  
OIP3. Looking for the predictions for surf conditions at the end of November at Byron Bay, Northern NSW. | EIP1. Looking for the website URL of “Cuil.”  
EIP2. Looking for the website URL of “Google.”  
EIP3. Looking for easy rocking stallion statistics.                                       | 6                                                                 |
| 17         | OIP1. Looking for some directions for implementing e-portfolio systems (“e-portfolio roadmap”) in the VET (Vocational Education & Training) sector over the next 3–5 years.  
OIP2. Looking for relevant research in the area of “Question–Answers (QA) research” in information systems.  
OIP3. Information on new tools that might be available for making natural language searching queries on the Web. | EIP1. Information on the structure of questions & answers in automatic FAQ system.  
EIP2. Looking for the reason why there is a financial crisis.  
EIP3. Looking for the reason why we age.                                           | 6                                                                 |
| 18         | OIP1. Information on machine vision grade cameras: Australian suppliers, quality, the best resolution available, price, and fully integrated solutions (onboard storages).  
OIP2. Information on how rotary engines work? What cars use rotary aside from Mazdas? Are they more efficient? What is the history of the engine? Is there a reason if not used more frequently?  
OIP3. Looking for the most likely power plants (hydrogen, ethanol, etc.) which will replace the combustion engine in modern cars. | EIP1. Information on the concept of “gige” in Wikipedia.  
EIP2. Looking for the website URL of “Wikipedia.”  
EIP3. Looking for the comparison between wankel engines and combustion engines.  
EIP4. Information on the future of the cars, like hybrid cars.  
EIP5. Looking for the comparison of hybrid car technologies.                      | 8                                                                 |
| 19         | OIP1. Overview information on the creative clusters development situation, especially in Australia, the U.K., and China.  
OIP2. Information on the differences between the concepts of “clusters,” “precincts,” and “parks.”  
OIP3. Looking for basic ideas about “media/culture convergence” in the creative clusters and the researchers who are doing research in this area. | None                                                                                                                        | 3                                                                 |
| 20         | OIP1. Looking for finite element modeling of cold-formed steel sections subject to local buckling.  
OIP2. Information on experimental investigation of cold-formed steel beams.  
OIP3. Information on inelastic reserve capacities of cold-formed steel beams. | EIP1. Information on the experimental finite element modeling.                                                            | 4                                                                 |
| 21         | OIP1. Information on the differences among liability, responsibility, and obligation, especially for the use of GNSS (Global Navigation Satellite System).  
OIP2. Information on the rank of Arsenal in British Soccer League: Who kicked the goal in last match in the team?  
OIP3. Information on the technology real-time kinematic (RTK) integrity and its application in the surveying: How many companies are doing research on RTK integrity? Check the company, such as Leica, Trimble, Topcon, and Ashtech. | EIP1. Information on the legal meaning of responsibility.  
EIP2. Information on the legal meaning of liability.                                                                             | 5                                                                 |
| 22         | OIP1. Information on correlation analysis for the reference in my Literature Review chapter.  
OIP2. Looking for presentation/solution/answer/suggestion/lecture notes on the basic skill of dealing with difficult people.  
OIP3. Information on the way to lose weight especially for people who often sit in offices. | EIP1. Information on correlation analysis in data mining.  
EIP2. Information on correlation analysis association rule mining.  
EIP3. Information on how to deal with difficult people in software engineering.  
EIP4. Looking for a diet plan for losing weight.                                     | 7                                                                 |
23 OIP1. Looking for interest rates for my home loan: the fixed & variable rates of Westpac, and compare them to the interest rates of other Australian banks.
OIP2. Information on U.S. presidential election: the likely winner based on polls, and historical comparison from turn around this far from an election.
OIP3. Information on nuclear power in Australia: how long would a plant be up and running, the CO2 decrease, and the recent history of safety (1990s–now).

24 OIP1. Information on washing machine company Fisher & Paykel: company history, experience implementing Kaizen for one of their divisions, and related organizational behavior theories to the case study of Kaizen adoption by Fisher & Paykel.
OIP2. Looking for SAP business solution: definition of solution and what modules they offer.
OIP3. Looking for sample of IT project framework.

25 OIP1. Looking for an example of text/discourse analysis from a sociolinguistic perspective and an example of discourse/text analysis of an Oscar Wilde text.
OIP2. Looking for general information about “Discourse Analysis.”
OIP3. Looking for a detailed synopsis of the play “The Importance of Being Earnest” by Oscar Wilde.

26 OIP1. Looking for the update information of the instrument “distress thermometer” (DT).
OIP2. Information on the function of shark cartilage, help relieve the pain of arthritis or reduce the occurrence of pain?
OIP3. Information on the function of omega-3, useful for decreasing cholesterol?

27 OIP1. For a holiday to Victor Harbor in South Australia, looking for what to do there and where we can stay.
OIP2. Looking for information about mobile phones in neighboring Indonesia.
OIP3. Information on the word “Beothuks” which came up in a novel set in Newfoundland in Canada.

28 OIP1. Looking for the best/most highly reviewed French restaurants that serve authentic food with a good atmosphere in Brisbane.
OIP2. Holiday packages to Vanuatu, Fiji, & Cook Islands. Looking for a good deal covering airfare, accommodation, and local tours if available.
OIP3. Information on how gender, class, and perceived identity affects language use in the TV series “Summer Heights High.”

29 OIP1. Looking for quality, economical, and value-for-money tour packages to tourist attractions in Queensland.
OIP2. Looking for a casual job in Brisbane that provides me full flexibility and the website is very user-friendly.
OIP3. Looking for the online cheapest flights to Sydney.

EIP1. Information on the big four banks in Australia.
EIP2. Looking for website URL of “New York Times.”
EIP3. Information on the U.S. presidential election date.
EIP4. Information on Uranium Information Centre.
EIP5. Information on nuclear waste disposal.

EIP1. Looking for the motivational theories adopted by Fisher & Paykel.

None

EIP1. Looking for the URL of “PubMed” database.
EIP2. Looking for the papers written by the author Yamagishi, A.
EIP3. Information on the Chinese meaning of the word “angiogenesis.”
EIP4. Looking for the website URL of “online dictionary.”
EIP5. Information on the dosage of shark cartilage in order to cure arthritis.

EIP1. Information on the relationship between Victor Harbor and Adelaide.
EIP2. Information on the relationship between Victor Harbor and Granite Island.
EIP3. Information on the distance between Monarto Zoo and Victor Harbor.

EIP1. Looking for “Edgewater Resort.”
EIP2. Looking for the reviews on “Edgewater Resort.”
EIP3. Looking for the reviews on “Cook Islands” packages for couples.
EIP4. Information on the research done by the author Larissa Mclean.
EIP1. Looking for tour packages from Brisbane to Byron Bay.
EIP2. Looking for cruise tour packages from Australia to anywhere.
EIP3. Looking for tour packages in Cairns.

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<th>Evolving Information Problem (EIP)</th>
<th>No. of Information Problems (OIP + EIP)</th>
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</thead>
</table>
| 30         | OIP1. Looking for experts’ statements on IT procurement and strategy, and the reason why procurement is essential for IT department.  
OIP2. Information on the latest movies or hit music.  
OIP3. Looking for the Chinese meaning of some IT acronyms (e.g., TCP, UDP, and the differences between the two).                                                    | EIP1. Looking for the website URL of “Wikipedia.”  
EIP2. Information on the concept of “procurement.”                                                                                                                                                                                                 | 5                                    |
| 31         | OIP1. Looking for the recipe for Italian noodles cooking.  
OIP2. Information on sunglasses shopping in Brisbane: shops, prices, and types, especially for those who are myopia/short-sighted.  
OIP3. Looking for the journals related to information systems and management included in SCI, EI, or ISTP. | EIP1. Looking for an English word with the meaning of “short-sighted.”  
EIP2. Looking for the real location of the virtual store “eyeglasses4you.”                                                                                                                                                                     | 5                                    |
| 32         | OIP1. Looking for papers and some comments on companies’ earnings forecasts.  
OIP2. Looking for papers with comments on companies’ earnings forecasting reputation.  
OIP3. Looking for papers of analysts’ earning forecasts about some companies.                                                                                                                                       | EIP1. Looking for the URL of “Google Scholar.”                                                                                                                                                                                                 | 4                                    |
| 33         | OIP1. Looking for significant information searching behavior models related to Web searches.  
OIP2. Looking for the literatures in query formulation/ modification analysis and their implications.  
OIP3. Looking for important conferences in image retrieval for paper writing plan.                                                                                                                                         | None                                                                                                                                                                                                                                   | 3                                    |
| 34         | OIP1. Looking for news and articles relating to the subprime credit crisis in the United States and its relation to the possible current recession in global financial markets.  
OIP2. Looking for financial and strategic data regarding an Indian biotechnology firm-Glenmark, and its financial performance relative to the biotechnology industry in India.  
OIP3. Looking for career opportunities in the venture capital industry globally.                                                                                                                                      | EIP1. Looking for the resolution of subprime crisis.  
EIP2. Looking for the qualifications for jobs in venture capital industry.  
EIP3. Looking for career opportunities in the venture capital industry in India.  
EIP4. Looking for salary information in Indian venture capital industry.                                                                                                                                                  | 7                                    |
| 35         | OIP1. Information on the newest Mary Jane shoes from Marc Jacobs.  
OIP2. Information on all infrastructure provider companies in Brisbane that have a large vehicle fleets division.  
OIP3. Information on the newest national code in good governance for Indonesia.                                                                                                                                        | None                                                                                                                                                                                                                                   | 3                                    |
| 36         | OIP1. Scholar papers about sea change: demographics, statistics, and background.  
OIP2. Information on mediation organizations as a potential future employment in the Gold Coast area.  
OIP3. Scholar papers about diasporic media.                                                                                                        | EIP1. Looking for the contact details of the Australia Institute.  
EIP2. Looking for the website URL of “Australia ABS.”  
EIP3. Looking for Australian government portals.  
EIP4. Scholar papers about diasporic telecommunication media.                                                                                                                                                                 | 7                                    |
| 37         | OIP1. Information on “Nutrition Transition” (NT): Who studied about it? What did they find? What is the significance? What sorts of projects/programs are doing now? Where? How about NT in Thailand?  
OIP2. Information on “Migrant”: How many Thais have moved to other countries? How many are Thais, male or female? Where do Thais locate in Australia? How many are Thais in Queensland? How about their health status? What is the theory of migrants?  
OIP3. Information on “Symbolic Interactionism” (SI): What is SI? Who created/developed/discovered SI? How?                                                                                                                   | EIP1. Information on migrants in Australia.                                                                                                                                                                                                 | 4                                    |
OIP1. My ex-boss’ contact information in order to get a recommendation letter.
OIP2. Information on the concept of “Flow.”
OIP3. Information on getting wireless access to QUT wireless service from my own MAC laptop and iPhone at my QUT office.

EIP1. Looking for the website URL of “McGraw-Hill publisher.”
EIP2. Looking for the email from Stephanie Beames in the Yahoo! email Inbox.
EIP3. Looking for the books on flow in QUT Library.
EIP4. Looking for a correct spelling of the book author’s name.
EIP5. Information on the author of the book *Emotional Intelligence*.

OIP1. Information on common strategies used in human resource management.
OIP2. Information on common traits across organizations within the biotechnology industry: size, skills, and competitive advantages.

EIP1. Looking for the URL of “PubMed” database.

None

OIP1. Looking for entertainment places in Brisbane.
OIP2. Information on “impact evaluation of university libraries” by some Web search engines.
OIP3. Renting a house near the city.

EIP1. Information on ethical problems in new drugs development for HIV treatment.
EIP2. Looking for the recipe for curry cooking.
EIP3. Information on tax refund.

EIP1. Information on grounded theory seminars in China.
EIP2. Information on grounded theory seminars worldwide.
OIP3. Conference information in nursing.

EIP1. Information on grounded theory seminars in China or in Australia.
EIP2. Information on grounded theory seminars in Australia.
EIP3. Looking for the website URL of “all conferences.”
EIP4. Conference information in nursing focusing on qualitative methods.

Total 126

M 3

95

2

221

5
were identified through the analysis of web search logs. A multitasking session took 1½ to 2 hr and was conducted on a laptop in a university laboratory. Each session consisted of the following steps: an introduction to the study, consent form, presearch questionnaire (Appendix A), a web search on self-generated IPs, a think-aloud activity (including thoughts, actions, and underlying reasons) performed concurrently with the web search, a postsearch questionnaire (Appendix B), and a postsearch interview. The web search logs and think-aloud data amounting to approximately 35 hr were recorded simultaneously by Camtasia Studio software. The postsearch interview was conducted to allow further elaboration of participants’ actions and underlying thoughts and was captured by an MP3 player which functioned as a digital recorder. A more detailed description of data collection can be found in Du (2010).

Data Analysis

The nature of multitasking, cognitive coordination, and cognitive shifts during web search were identified through the measures of multitasking sessions, cognitive coordination occurrences, and types of cognitive shifts from the observed data, respectively.

Multitasking sessions. Multitasking sessions were observed through the analysis of web search logs. A multitasking session was demonstrated as behaviors including the ordering and switching between multiple IPs (tasks); the generation of evolving IPs (EIPs), including serendipitous browsing activities; and the utilization of multiple search systems, queries, and windows/tabs browsing. Participants’ responses associated with the following questions in the postsearch questionnaire were considered as self-explanations of their recorded logs of multitasking behaviors. Questions included: How and why did you order your multiple IPs? Were there any EIPs generated during web search? What were they? And how did you switch IPs (tasks) from one to another?

Cognitive coordination occurrences. Cognitive coordination occurrences were identified through the analysis of the transcripts of participants’ think-aloud utterances in conjunction with search logs (i.e., verbal protocol analysis of the utterance-search segments). The transcripts and web search logs were segmented into cognitive coordination occurrences. A cognitive coordination occurrence was demonstrated within the following scenario (which could be iterative as needed):

- IP identification
- Search terms (re)selection and queries (re)formulation
- System output in response to the search strategies
- Participants’ utterances including relevance and magnitude judgment feedback, and sense-making process relating to the system output
- Participants’ strategies and actions relating to the relevant items retrieved.

Types of cognitive shifts. Types of cognitive shifts were identified, for one aspect, through the analysis of pre- and postsearch questionnaires. A cognitive shift was indicated as a change of perceptions in terms of information problem understanding and knowledge contribution before and after web search. Content analysis and descriptive statistics revealed participants’ shifts in cognition before and after web search. In addition, participants’ ongoing cognitive shifts during the web search process were captured by the web search logs and reflected on their think-aloud utterances, for example, from one state of relevance judgment to another state of query formulation. The analysis of the utterance-search segments provided the details of participants’ dynamic cognitive states and shifts between the states.

Coding scheme development. Based on the measure units of multitasking, cognitive coordination, and cognitive shifts, a microanalysis of each measurement unit was conducted to identify the occurrences and nature of multitasking, cognitive coordination, and cognitive shifts during the 42 web searches. The analysis adopted the grounded-theory approach (Strauss & Corbin, 1990). The resulting categories of multitasking, cognitive coordination, and cognitive shifts during web search were grounded in the data. The coding scheme, consisting of 13 categories (Table 3), was developed and refined through an iterative process of concurrently examining and categorizing the transcript of each user’s think-aloud utterance with his or her web search logs (i.e., utterance-search segments).

The utterance-search segments were coded in order of occurrence in the form of a flowchart. Figure 2 illustrates how the analysis of multitasking sessions, cognitive coordination occurrences, and types of cognitive shifts was conducted and how each code in the coding scheme was used.

Details interpretations of each code along with the instances from the participants are reported in the Results section. A second coder was invited to check a sample of two (5%) utterance-search segments for consistency and reliability, and the coding results were compared using intercoder reliability checks. Intercoder agreement reached the level of 0.81, which indicates an acceptable level for drawing conclusions in qualitative research (Krippendorff, 1980).

Results

RQ1: How Do Users Conduct Web Searches on Multiple IPs?

The behavior of multitasking during web search was represented as multiple IPs search ordering, EIPs development, IP searching task switching, and multiple web search sessions within a particular IP searching.

Search ordering of multiple IPs. Participants prioritized the searching order among three OIPs. Research topic was
always given priority for the first, second, or third search, followed by topics on Assignment, Job, and Travel information. Table 4 shows the factors that affected participants’ IP ordering.

Table 4 shows that multiple IPs search ordering was affected by the following factors: problem importance level, random ordering, ease of finding information, task logic, problem urgency level, task interest, problem familiarity level, and future usefulness. Problem importance level–high to low (n = 12, 29%), randomness (n = 11, 26%), and ease of finding information–high to low (n = 10, 24%) were the three major factors in determining IP search ordering. These were followed by task logic (n = 7, 17%), problem urgency level–high to low (n = 6, 14%), task interest (n = 6, 14%), ease of finding information–low to high (n = 4, 10%), and problem familiarity level–high to low (n = 3, 7%). Problem importance level–low to high (n = 2, 5%) and future usefulness (n = 2, 5%) were seldom considered when ordering the searching tasks.

An interesting finding also emerged: Over 40% of the participants determined the search ordering based on the consideration of several factors rather than a single factor. This is more complex search ordering than was previously observed. For example, Participant 3 stated that

the first one of getting a cheap bicycle was a real problem in my life and I needed it now. I knew it would be easier for me to find information on other two problems. The third one was regarded to my interest. I searched it just for fun.

Three factors—high problem urgency, task interest, and ease of finding information on the Web (low-to-high)—were considered together when ordering his or her three OIPs.

**Generation of EIPs.** An IP is treated as dynamic; hence, the problem may evolve and change over time, probably due to the learning and cognition in context during IR interaction. The evolution of IPs is a significant feature of dynamic and interactive web searching behavior (Ingwersen & Järvelin, 2005; Spink, Park, & Koshman, 2006). Compared to the OIP which was planned by participants, the generation of an EIP entailed an attribute of improvisation. Unlike Bates’ concept of evolving search, which was evolving query (Bates, 1989), we found that what was evolved during web search was not merely the query but the IP context involving search queries, search sessions, users’ cognitive moves, and so on.

Our findings show that over 70% of the participants developed EIPs (Table 2, third column). The total number of EIPs was 95. The mean number per search was 2, with a range from 1 to 8. EIPs were presented as changed or as totally new ones compared to OIPs. For example, Participant 9’s third OIP was about scholarships for graduate students in Australian universities. He or she then refined the scope to available scholarships for international graduate students (i.e., changed IP); Participant 8’s third problem was for information on a day tour in Malaysia, including tour guides and the cost involved. A new IP was developed to look for a transit visa at the Malaysia airport.

**Task switching between multiple IPs searching.** Participants worked on 126 OIPs and generated 95 EIPs during web search. They were found to switch search tasks between these 221 IPs; that is, each participant switched search tasks between approximately five IPs, on average. Information task switching behavior was characterized as a process of ceasing to search or browse information on one task and proceeding with another information task. Three types of information searching task were identified. The first type was searching on an original IP (SOIP). SOIPN (n = 1, 2, 3) means searching on the nth OIP. The second type was searching on an EIP (SEIP). SEIPN (N = 1, 2, 3, ..., n) stands for searching on the nth EIP. The third type of information searching task was serendipitous browsing (SB) on other topics, which was instigated by visual cues prompting the transfer of attention to other interesting topics. SBN (N = 1, 2, 3, ..., n) means browsing on the nth different topic.
Study Participant 11 — OP

Google
(Web search engine selection) — PSS & STR

Trip to New Zealand
(query) — PSS & STR

View the returned results & Scroll
Maybe actually I just look for the air tickets." — TCF & STR & EVIA

Cheap flights, maybe I can check that first." — TCF & EVIA

Click on the link and open it
Browse information on the opened website

"Oh, that's Flightcentre website." — SLR & VE

Do the search on the opened website

Study Participant 11 — EP1

Flightcentre
(www.flightcentre.com.au)
(Website searching feature selection) — PSS & STR

From Brisbane
To Auckland
03/01/2009
15/01/2009
(query) — PSS & STR & IT & TOP

"See how much does it cost? It's about over $600 from Brisbane to Auckland, quite expensive." — SLR & VE

"I'd like to make notes of the cheapest one it returned. It's about $323.61. 6pm from Auckland to Brisbane, that's quite good." — PSS & SLR & STR & VE

"I think the expensive rate from Brisbane to Auckland may result from the date I choose, I choose Saturday, a lot of people go to travel so maybe I can choose other days, like Jan 5th — SLR & VE

"Back" feature in IE browser, back to the previous searching website

From Brisbane
To Auckland
05/01/2009
15/01/2009
(query) — PSS & STR

"Yes, it's much cheaper now, $300—$400." — SLR & VE

"I'd like to make notes about this cheapest price which is $305.11, 8.05am, Jan 5th." — PSS & SLR & STR & VE

"Back" feature in IE browser, back to the Google results list

Click on the 2nd Ad by Google (advertisement — Virgin Blue) and open it

From Brisbane
To Auckland
05/01/2009
15/01/2009
(query) — PSS & STR

Virgin Blue
(www.virginblue.com.au)
(Website searching feature selection) — PSS & STR

From Brisbane
To Auckland
05/01/2009
15/01/2009
(query) — PSS & STR

"Yes, it's cheaper, only $34.21, than the Flightcentre price. About $40 cheaper." — SLR & VE

"But the time is not really good, so they offer a cheaper price, and the price from Auckland to Brisbane is more expensive than the price offered by Flightcentre." — SLR & VE

"Back" feature in IE browser, back to the Google results list

Google
(Web search engine selection) — PSS & STR

Jetstar
(query) — PSS & STR & IT & TOP

Click on the 1st entry link and open it, "try jetstar, maybe it's quite cheap." — TCF & STR

Jetstar
(query) — PSS & STR & IT & TOP

(Website searching feature selection) — PSS & STR

From Brisbane
To Christchurch
06/01/2009
15/01/2009
(query) — PSS & STR & IT & TOP

"Only Christchurch is available, I don't care which city I go first as I'll go to both north island and south island." — SLR & VE

"It's about $253, the cheapest one. But need to go to Christchurch instead of Auckland first, anyway, that's good deal for international student." — SLR & VE

"When I get back, I'll book $279, and the back time is good too." — SLR & VE

Make notes of the price — PSS & STR

"I'm now looking for the previous 3 days, whether much cheaper or more expensive. Then I'll get an idea which day is best for me." — TCF & STR

Click on the "previous 3 days" link on the website

"Oh, more expensive." — SLR & VE

Click on the "next 3 days" link on the website

"Wow, much cheaper! If I go to New Zealand on Jan 6th, it'll be $20 cheaper, and if I can get back one day later, only costs $193, as still 10 days trip. So time is an important issue for the price. Good deal." — SLR & VE

Click on the "next 3 days" link on the website again

Jan 19th also costs $193, same price as Sun and Mon, but the flight time on Sunday is quite early in the morning. The time for Monday Jan 19th is much better: I may consider Jan 19th. Oh, I have a new idea now, I may go on Jan 6th and back on Jan 19th for the Jetstar price. Now it's about $213 to go and $193 to back, good idea." — SLR & VE

"I'd like to compare the same day price to Christchurch with Virgin Blue, to find out which one is much cheaper then I can decide." — TCF & STR

"Back" feature in IE browser, back to the Virgin Blue website

Virgin Blue
(www.virginblue.com.au)
(Website searching feature selection) — PSS & STR

From Brisbane
To Christchurch
06/01/2009
15/01/2009
(query) — PSS & STR

"The cheapest one I can find here is about $195, wow, back flight is only $115, quite cheaper than Jetstar offers, also with good time. I got an idea now, I decide to take Virgin Blue to New Zealand, very good price." — SLR & VE

"My second problem is looking for information regarding to the activities I can do in New Zealand. Also, I'd like to use Google." — TCF & STR

Google
(Web search engine selection) — PSS & STR

FIG. 2. An example of the analysis for multitasking, cognitive coordination, and cognitive shifts by using the coding scheme (Participant 11).
FIG. 2. (Continued)
Participants switched back and forth between the three types of web search tasks. The task of SB was not found to be a distinct behavior, as it took place in only five cases (the searches of Participants 5, 8, 17, 38, and 41). Therefore, this study focuses on SOIP and SEIP, reserving the analysis of SB to further research. All of the participants’ information searching task switches were classified into four patterns (Table 5).

Table 5 shows that from the simplest to the most complicated mode, Patterns A, B, C, and D were four sorts of task switching patterns. Pattern D was the major pattern, in which 43% of the participants switched between SOIPs and three or more SEIPs. The task switching behavior under this circumstance appeared very active: Participants frequently switched from one IP searching to another and jumped back and forth. The second most frequent pattern was Pattern C (29%), in which one or two EIPs were generated in addition to SOIPs, followed by Pattern A (21%), in which participants switched between three OIPs by order and without any iteration. There were only three occurrences of Pattern B (7%), in which participants switched back and forth between their three OIPs.

**Multiple web search sessions.** We define a web search session as a certain period devoted to a particular IP search, referring to users’ practice of submitting the entire sequence of queries through the interactions with web search systems over time in windows/tabs. Multiple web search sessions take place during a web search episode when multiple IP searches have occurred. This description more closely reveals users’ multiple search sessions than do prior studies (Spink, 1996), in that it reflects a comprehensive picture of what multiple search sessions include and not only multiple queries but also the interactions with multiple web search systems in multiple opened windows/tabs for multiple IPs.

Our findings show that for a particular IP search within a web search session, the number of submitted queries varied from 1 to 12 (M = 5); the number of the employed web search systems varied from 1 to 3 (M = 2); and the range of the opened windows/tabs was 1 to 13 (M = 4). The complexity level of a web search session depended on how many queries, web search systems, and windows/tabs were employed. Forty-two participants conducted a total of 315 search sessions (range = 3–16, M = 7.5). Twenty-six percent of the participants reported conducting 10 or more search sessions. Multiple web search sessions were related to the current IP evolving or changing.

Interestingly, the opened windows/tabs consisted of a primary searching window or tab and several secondary searching windows/tabs linked from the primary one. A common operation is that participants went back and forth between several secondary windows/tabs and the primary one. The move between multiple windows/tabs appeared chaotic. Nevertheless, participants believed that multiple windows/tabs browsing at the same time was an efficient way of time management. The more adaptive web searching tools should differentiate between the primary window or tab and secondary windows or tabs, which may reduce users’ switching and relocating time between different windows/tabs.

**RQ2: What Levels of Cognitive Coordination Occur During Web Search?**

A total of 5,200 cognitive coordination occurrences were identified during the 42 web searches. The mean number per web search was 124, with a range from 40 to 189 (Table 6).
TABLE 6. Occurrence of cognitive coordination during user–Web interaction.

<table>
<thead>
<tr>
<th>Level of cognitive coordination</th>
<th>No. of searches of 42</th>
<th>No. of occurrences</th>
<th>%</th>
<th>M</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1: Task coordination (TC)</td>
<td>IT 42</td>
<td>280</td>
<td>5</td>
<td>6.7</td>
<td>3–16</td>
</tr>
<tr>
<td>Level 2: Coordination mechanism (CM)</td>
<td>TRF 25</td>
<td>78</td>
<td>1.5</td>
<td>3.1</td>
<td>1–9</td>
</tr>
<tr>
<td></td>
<td>CRF 42</td>
<td>1,146</td>
<td>22</td>
<td>27.3</td>
<td>4–67</td>
</tr>
<tr>
<td></td>
<td>MF 34</td>
<td>148</td>
<td>3</td>
<td>4.4</td>
<td>1–14</td>
</tr>
<tr>
<td></td>
<td>TCF 42</td>
<td>446</td>
<td>8.5</td>
<td>10.6</td>
<td>2–29</td>
</tr>
<tr>
<td></td>
<td>SLR 42</td>
<td>1,346</td>
<td>26</td>
<td>32.0</td>
<td>4–56</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3,164</td>
<td>61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3: Strategy coordination (SC)</td>
<td>PSS 42</td>
<td>1,614</td>
<td>31</td>
<td>38.4</td>
<td>13–71</td>
</tr>
<tr>
<td></td>
<td>GS 42</td>
<td>142</td>
<td>3</td>
<td>3.4</td>
<td>2–7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,756</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5,200</td>
<td>100</td>
<td>124</td>
<td>40–189</td>
</tr>
</tbody>
</table>

FIG. 3. Levels of cognitive coordination.

Cognitive coordination occurrences were further classified into three levels: Level 1: task coordination (TC); Level 2: coordination mechanism (CM); and Level 3: strategy coordination (SC) (Figure 3).

In the following section, each cognitive coordination level is described, and examples are provided. The examples were excerpted from utterance-search segments from the study participants (SPs).

Level 1: Information TC. Information TC represented the coordination process between information tasks (IT), including OIP identification, EIP generation, problem searching task switching, and windows/tabs browsing. During the 42 searches, there were 280 TC occurrences (5% of the total coordination occurrences), with a mean of 6.7 TC occurrences per search. Detailed next are examples of coordination at task level:

- “The second problem I’m trying to find out the (medical) function of shark cartilage.” (OIP identification, SP26)
- “I met a word ‘angiogenesis’ in this article. What is angiogenesis? I need to look it up in the dictionary before continuing the searching.” (EIP generation, SP26)
- “Now move on to the third problem.” (Information searching task switching, SP26)
- “Now I am using right click on this link and open it in a new tab, browsing information on the opened tab.” (Tabs browsing, SP36)

Level 2: Cognitive CM. The cognitive CM was the underlying system supporting information task coordination and provided an explanation on how the CM among multiple information tasks was achieved. There were 3,164 CM occurrences identified during the 42 searches, representing 61% of the total number of coordination occurrences. Web search CMs involved a series of cognitive processing activities including term relevance feedback, content relevance feedback, magnitude feedback, tactical review feedback, and self-learning and regulating.

- **Term relevance feedback** occurred when a term(s) was identified within the retrieved results and used to modify the subsequent search query. For example:

  - “Oh, Google provides related searches to ‘shark cartilage arthritis.’ I will try this [as search keywords].” (SP26)

  Term relevance feedback (25 of 42 searches) did not take place at each search, which means identifying a term within the system that returned results was not an essential behavior for a web search interaction.

- **Content relevance feedback** represented a relevance judgment made on a system returned entry result before clicking on the corresponding URL link. For example:

  - “Here we go, this one is good.” (Followed by clicking on the third entry link, SP26)
During the 42 searches, participants provided content relevance feedback within a total of 1,146 coordination occurrences. This represented 22% of the total coordination occurrences, with a mean of 27.3 content relevance feedbacks per search.

Magnitude feedback was a judgment made based on the size of system output followed by a reformulated query or viewing the returned results. For example:

- “No results, what happened?” (Followed by reformulating the search query, SP26)
- “Thirty-four related articles and 2 reviews turned up. That’s good.” (Followed by viewing the returned results, SP26)

Magnitude feedback (34 of 42 searches) did not take place at each search, which means judging the size of system output was not an essential behavior for a web search interaction.

Tactical review feedback represented strategy-related adjustments which were made based on the retrieved results, such as decisions on changing a search keyword or changing an information source. For example:

- “I may add another keyword to make sure that I won’t miss any information.” (Decision on changing a search keyword, SP26)
- “It seems that I need to pay for it. I may (try) QUT library database to find the full text.” (Decision on changing an information source, SP26)

During the 42 searches, participants made tactical review feedback within a total of 446 coordination occurrences, representing 8.5% of the total coordination occurrences, with a mean of 10.6 tactical review feedbacks per search.

Self-learning and regulating represented users’ examination on the opened website/webpage content followed by a sense-making process. For example:

- “This is not what I want.” (After browsing the opened website content, SP26)
- “It makes sense. The reason of using shark cartilage in the treatment of arthritis is that it can help to build. . . . This is a high quality research, quite good. So shark cartilage is useful to the treatment of arthritis.” (After reading through the .pdf document, SP26)

Participants were found to frequently engage in self-learning and regulating in continuous states of knowledge construction based on new information input. Users engaged in self-learning and regulating within a total of 1,346 coordination occurrences. This represented 26% of the total coordination occurrences, with a mean of 32 self-learning and regulating actions per search.

Level 3: Cognitive SC. A cognitive strategy is a mental plan that guides how one uses sensory input and directs motor actions (Sangster, Beninger, Polatajko, & Mandich, 2005). SC represents a strategic plan for solving IPs within the resources available. The available resources in this study included the usable web search tools as well as the limited time frame of 1-hr searching duration. A total of 1,756 (34%) coordination occurrences were related to the strategies adopted during 42 searches. Two types of cognitive SC were identified: problem specific strategy and global strategy.

Problem-specific strategy referred to the collection of tactics on web searching tools that participants adopted for a particular IP solving such as web search systems selection, search queries (re)formulation, results set (pages) review, and the relevant results savings. For example:

- “Hopefully I can find something in the academic database. But I cannot be sure. I know it’s a really narrow topic.” (Search systems selection, SP28)
- “The first problem I’m going to solve is to find updated information about instructions on ‘distress thermometer’ used in my PhD study. I enter ‘distress thermometer’ in the simple search box.” (Search query formulation, SP26)
- “I am clicking on the ‘next’ link at the end of Google results list to check information shown on the next page.” (Next result page review, SP26)
- “I would save this pdf document to the desktop.” (Relevant results saving, SP26)

There were 1,614 problem-specific SC occurrences, representing 31% of the 5,200 total coordination occurrences, with a mean of 38.4 per search. The problem-specific strategy was the most frequent coordination occurrence. This indicates that users made a purposeful searching plan along the web search on each IP.

Global strategy was an overall plan of the tactics on searching duration and time allocation between multiple search tasks to solve all of them within the limited time frame. There were 142 global SC occurrences, representing 3% of total coordination occurrences. For example:

- “Oh, time is up, ok, stop here.” (Searching duration, SP28)
- “What time is now? 25 minutes left? I may keep looking at this problem.” (Time allocation, SP22)

In terms of web search duration, nearly 40% of the participants used the entire 1-hr searching time, around 26% of the participants used three fourths of the 1-hr searching time, another 21% of the participants spent approximately two thirds of the 1-hr searching time, and the remaining 14% spent less than a half hour. With regard to time allocation, 91% of the participants unevenly allocated search duration between multiple IPs. In 13 (31%) cases of 42 searches, almost a half hour was spent searching on one IP and only a few minutes on another.

Time allocation was found not a random behavior but a conscious strategy. For example, in the postsearch interview, Participant 28 said that I knew I would need to spend a lot of searching time on problem 3, so I left it till last. Problem 1 was the most straightforward out of the three and I believed it would need the shortest time to find the information.

Park (2008) also found that participants were well aware of spending time in an optimal way among multiple information tasks. Coordinating activities entailed task switching and strategic search planning, which were closely related to time management.
In summary, participants experienced the most coordination at the mechanism level (61%), followed by 34% of coordination at the strategy level and 5% of coordination at the task level. The cognitive CM played an important role in a smooth multitasking Web search.

Transition analysis of three cognitive coordination levels. Cognitive coordination occurrences also can be analyzed in sequences. Participants transitioned from one cognitive coordination level to another. For example, Participant 22 began with problem-specific strategies of selecting Google as the search system and entering “correlation analysis” as the search query at the SC level, then shifted to content relevance feedback on the second returned result in that “it may be not very academic,” followed by a tactical review feedback of “I need to change the search query” at the CM level. The transition between cognitive coordination levels was shown to be a common behavior to conduct web searching.

There were 5,133 cognitive coordination level transitions during the 42 web searches. A mean transition was 122 per search, with a range from 37 to 187. The pattern of sequence was CM (62%), followed by another level of cognitive coordination, SC (33%), followed by another level of cognitive coordination, and task coordination (5%), followed by another cognitive coordination level. The most frequent transition occurred between one type of CM and another type of CM.

RQ3: What Types of Cognitive Shifts Occur During Web Search?

A web search interaction also is the cognitive process during which users experience various cognitive shifts. Participants were found to engage in two types of cognitive shifts: holistic shifts and state shifts. Holistic cognitive shifts were measured before and after web search by means of data in pre- and postsearch questionnaires. Holistic shifts were users’ cognitive changes with respect to an IP, including shifts in IP understanding, information problem stage, information seeking stage, shifts in personal knowledge, and the perception of the contribution to the IP resolution.

Shifts in the IP understanding. Some participants experienced different levels of change in terms of IP understanding. The same participant had different understanding on three cognitive coordination levels—for example, from the stage of problem recognition to resolution. Around 39% of the participants stayed in the same information problem stage, and the remaining 10% of the participants experienced negative shifts in the IP stage.

Shifts in the information seeking stage. Six information seeking stages have been identified: information initiation, selection, exploration, collection, formulation, and presentation (Spink, Wilson, Ford, Foster, & Ellis, 2002). Our results show that some participants experienced different levels of shifts in their information seeking stage due to the web search. Nearly 38% of the participants shifted to a forward/specific seeking stage, such as from the stage of information initiation to collection. Around 34% of the participants shifted to a backward/broad seeking stage. Nearly 17% of the participants remained in the same information seeking stage, and over 10% of them were situated at multiple seeking stages.

Shifts in personal knowledge. Some participants experienced different levels of shifts in their personal knowledge on each IP. More than 60% of the participants reported that the searching interactions were positive to their knowledge contribution. Nearly 31% of them stayed in the same knowledge stage, and over 7% of them reported that negative shifts occurred in their personal knowledge.

Judgments on contribution to the IP resolution. Participants reported levels of holistic shifts—forward, backward, and no shift—with respect to the IPs understanding and knowledge contribution. Most participants (67%) selected the 4 or 5 on the 5-point Likert scale, indicating the searching interactions significantly contributed to the resolution of their IPs. Namely, web search had a positive impact on their IP solving. After web searching, most participants had a clearer understanding of the IPs, and positive changes occurred at the IP stage, seeking stage and personal knowledge; thus, the contributions to the IPs resolution were achieved.

Cognitive state shifts were the cognitive changes in focus of the interactions between a user and a web search system with respect to the user’s cognitive states. These shifts reflected how participants moved between different cognitive states, such as from the state of evaluation on the search results to the state of query reformulation. State shifts were recognized through the “cue words” which indicated a change. These cue words varied from the subtle to the obvious; therefore, utterance-search segments were studied carefully to perceive such cues.

Types of cognitive states. Five types of cognitive state were identified in the web searching context:

- **Topic (TOP):** the state focusing on a specific subject area or an IP guiding the search. Cue words: “problem,” “topic,” “look for,” “find,” “next,” and so on
- **Strategy (STR):** the state concerning the search strategies adoption and adjustment, such as term selection, query (re)formulation, and web search system selection. Cue words: “query,” “change,” “Google,” “next page,” “save,” “make notes,” and so on
The state-shifts data showed that participants changed from one cognitive state to another. Most shifts (86%) occurred between the states of STR, EVA, and VIE. Participants recurrently diverted their attention/cognitive state from the adoption of the search strategy to the following evaluation of the search results, then to the examination of the opened URL link. Fewer shifts (24%) took place between the state of TOP or OVE and the other types of state. There were no shifts directly from TOP to EVA or from TOP to OVE; however, TOP to STR was found to be a frequent type of shift, which means that participants regularly identified a search topic, followed by the adoption of a certain search strategy.

Discussion

Our findings confirm and extend the findings of previous studies on multitasking web search and cognitive shifts research. To our knowledge, this is the first study to explore in detail the behavior of cognitive coordination during web search. The exploration of multitasking, cognitive coordination, and cognitive shifts extends the web search model to include cognitive coordination and shifting mechanisms within multitasking web search. It is fundamental to basic research toward theories and models of interactive IR, and to applied research and development toward the improvement of the user–IR system interaction.

Multitasking During Web Search

Our findings provide valuable insights into multitasking information behavior in the web search context. Multitasking was found to be a prevalent behavior in web search. The multitasking web search included the activities of ordering multiple IPs, generating EIPs, and switching search tasks. These activities occurred within multiple web search sessions. Multiple web search sessions reflect an important trait of multitasking web search. Web search sessions are ubiquitous, but little explored, phenomena.

Our results support Spink’s (1996) call for further exploration into the dimensions of the multiple search sessions model. Previous studies examined search sessions within a single IP and a single IR system (Huang, 1992; Lin, 2005; Saracevic, Mokros, & Su, 1999). Our research expands the findings to the context of multiple IPs searching. Three facets of a web search session (i.e., queries, search systems, and windows/tabs) were identified from the analysis. Users submitted the sequence of several queries into multiple web search systems over time in multiple opened windows/tabs. Each IP searching occurred in a web search session. Multiple web search sessions are applicable to multiple IPs searching. The findings provide implications for the development of a multiple search sessions model in the web search context.

Our findings show that multiple IPs during web search were ordered with intention or at random. Three major factors in determining non-assigned information problems searching order were problem importance level (high to low), randomness, and ease of finding information (high to low). The results extend Spink, Park, and Koshman’s (2006) findings in which personal interest and problem familiarity level were two major factors affecting assigned IPs ordering. EIP was found to be an important element during successive web searches. Beyond OIPs, 95 EIPs were generated by over 70% of the participants. Each participant was observed to search for five information searching problems, on average. The results confirmed that a continuum of search sessions was possibly driven by an EIP (Spink, 1996, 2004).

Previous research has paid limited attention to searching task switching, including EIPs (Spink, Wilson, et al., 2002). The results of our study show that the switched searching tasks occurred between multiple IPs, including OIPs and EIPs. Four task switching patterns were identified. The most frequent pattern (43%) was the switch between three OIPs searching and three or more EIPs searching. Regarding the reasons for the generation of EIPs and switching between

<table>
<thead>
<tr>
<th>Type of cognitive state</th>
<th>No.</th>
<th>%</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic (TOP)</td>
<td>281</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Evaluation (EVA)</td>
<td>1,366</td>
<td>26</td>
<td>33</td>
</tr>
<tr>
<td>Strategy (STR)</td>
<td>2,053</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>View (VIE)</td>
<td>1,348</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Overview (OVE)</td>
<td>142</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>5,159</td>
<td>100</td>
<td>124</td>
</tr>
</tbody>
</table>

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Previous research has paid limited attention to searching task switching, including EIPs (Spink, Wilson, et al., 2002). The results of our study show that the switched searching tasks occurred between multiple IPs, including OIPs and EIPs. Four task switching patterns were identified. The most frequent pattern (43%) was the switch between three OIPs searching and three or more EIPs searching. Regarding the reasons for the generation of EIPs and switching between
multiple searching tasks, previous studies have considered that SB and interest shift were two causes (Spink, 2004). An SB episode involved users browsing for other information due to visual cues. Interest shift was concerned with users’ emotion. Users became bored with one information task and wanted to proceed with another one. The results of this study confirmed that these two factors existed, but were minor. The occurrences of cognitive coordination were found to be a major factor of developing EIPs and supporting multiple tasks switching.

Cognitive Coordination

Cognitive coordination was found as a significant behavior during the course of web search. Users constructed a conscious reasoning and coordination process. Information tasks were switched based on cognitive feedback, including relevance judgment, self-learning, regulating process, and tactical review feedback. The strategy of the time allocation between multiple tasks also mainly affected the behavior of task switching. Therefore, task switching not only occurs at the physical multitasking level and the emotional level but also is a behavior correlated closely to humans’ cognitive processing. Users were found to experience complicated cognitive coordination processes embedded within web search. The cognitive coordination occurrences were further classified into three different levels: information TC, CM, and SC. Figure 4 shows the interplay structure between the three cognitive coordination levels.

Coordination mechanisms, together with SC, support multiple information tasks coordination. The three-level cognitive coordination during web search occurs as sequences. Transitions take place between three cognitive coordination levels; that is, TC ↔ CM, CM ↔ SC, and SC ↔ TC. The transitions also occur between individual types of CMs and between individual types of cognitive strategies. Our findings show that the most frequent transition (62%) was the CM level followed by another cognitive coordination level. The coordination mechanism involved types of cognitive-processing activities—most of them were content relevance feedback (36%) that made relevance judgments on the returned results, and self-learning and regulating process (43%) intended to make sense of the gathered information. This study meets Spink’s (1997) call for further investigation on the nature and occurrence of interactive feedback within end-user searching. Adapted from Spink’s (1997) feedback mechanism, which was investigated under a mediated IR search environment, the cognitive CM was investigated in the end-users’ web search context. Different findings have emerged accordingly:

- Feedback mechanism was initiated either by a user or a search intermediary whereas the cognitive coordination mechanism was initiated exclusively by a user.
- New meaning was given to the cognitive CM. For example, tactical review feedback in Spink’s (1997) study was described as users’ input followed by a strategy-related judgment to display the search-strategy history influencing the subsequent query. In our study, tactical review feedback was viewed as strategy-related adjustments (replanning) based on the review of retrieved results, and represented as the decision either on changing a search keyword or changing an information source.
- In addition to content relevance feedback, the self-learning and regulating process was observed as an important interaction of CMs in which users examined information shown on the opened website/webpage, followed by a sense-making process.
- Magnitude feedback in Spink’s (1997) study was found to be a major interaction beyond other types of feedback, representing 45% of the observed feedback occurrences. However, our study found magnitude feedback constituted only 3% of all the coordination occurrences, which was observed as a trivial interaction mechanism. It indicates that users did not pay more attention to the size of system output during web search.

Cognitive Shifts

Cognitive shifts were found to be an essential element of web searching, with two types of cognitive shifts: holistic shifts and state shifts. Measured prior to and after web search, holistic shifts were the changes of users’ perceptions of IPs and overall information evaluation. The results support Spink’s (2002) and Spink and Dee’s (2007) findings that users reported forward, backward, and no shift in cognition with respect to IP understanding and knowledge contribution, and some users reported different degrees of the shifts. In
most situations, users experienced forward shifting. Results show that 67% of the participants reported that the web search interaction significantly contributed to the resolution of their IPs.

Moreover, the dynamic and ongoing shifts between users’ cognitive states during web search were explored in the present study. State shifts were the changes in focus of the interaction between a user and a web search system with respect to the users’ cognitive states. State shifts reflect users’ focus changes between different cognitive states. Five types of cognitive state were identified, including topic, strategy, evaluation, view, and overview; each of them stands for a distinct phase in the web searching process. The results demonstrate that the most experienced cognitive states were strategy, evaluation, and view, which constituted more than 90% of the total states.

Similar results were reported in Robins’ (2000) study, where users’ concentrations were more on strategy and evaluation. Together, strategic and evaluative foci constituted 60% (44 and 16%, respectively) of all foci occurrences. The majority of users’ focus dealt with input and output from the search system. Most of the shifts also were found to occur between the states of strategy, evaluation, and view. Users recurrently diverted their cognitive state/attention between the adoption of search strategy, the evaluation of the upcoming search results, and the examination of the opened webpage.

We further propose that the cognitive state shifts experienced during the search interactions have effects on the holistic cognitive shifts that occurred after web search (Figure 5).

Users make evaluations on the search strategies (STR), on the system returned results (EVA), and on the gathered information (VIE) against the searching aim. The occurrences of these states affect the shifts of holistic cognition on IP understanding and overall judgment of the contribution to the IP resolution due to the search interactions. It is a sort of impact of the process on the outcome. The forms of the effect and how the effect is produced are important issues that deserve further attention.

**Revised Multitasking, Cognitive Coordination, and Cognitive Shifts Relationship Model**

The research to this point has laid a foundation to explore a relationship between multitasking, cognitive coordination, and cognitive shifts during web search. The theoretical model (Figure 1) based on the review of literature was revisited with the empirical findings. A revised model (hereinafter, the MCC model) was developed to present the relationship between multitasking, cognitive coordination, and cognitive shifts (Figure 6).

The MCC model illustrates how the behaviors of multitasking, cognitive coordination, and cognitive shifts interplay during user–web interaction. It also illustrates how the searching on multiple IPs is conducted and how users’ cognitive shifts occur. Web search is a dynamic interaction between a user and web search systems during which IPs ordering, EIPs generating, searching task switching, windows/tabs browsing, and task and mental coordinating occur, and at a deeper level, cognitive shifts take place. Web search starts from the identification of OIPs which initiate and motivate the web search. EIPs are likely to be generated during the successive web search. The searching task switching occurs between multiple IPs, including OIPs and EIPs, within multiple web search sessions.

The explicit task-level coordination is closely linked to multitasking behavior. The implicit cognitive processing
mechanism level coordination and strategy-level coordination support and explain the task-coordination process, especially for the development of EIPs and searching task switching. The coordination mechanisms, including feedback and learning and regulating processes, directly result in users' shifts between cognitive states, including strategy, evaluation, and view states during web search. Furthermore, the occurrences of state shifts affect users’ holistic shifts of perception on IP understanding and results evaluation after web search.

The MCC model highlights the role of three cognitive coordination levels—task, mechanism, and strategy—in support of the behavioral moves of multitasking task switching and cognitive construction in state and holistic shifts during the course of web search. Cognitive coordination is a vital psychology mechanism supporting multitasking web search and provoking the occurrence of cognitive shifts. Cognitive coordination is the hinge linking together multitasking and cognitive shifts to move users through dynamic and interactive web searches. Without cognitive coordination, neither multitasking web search nor complicated mental shifting will occur.

Limitations

We prompted each participant to bring three IPs for the web search. The requirement allowed the researcher to investigate users’ multitasking behavior. Meanwhile, it also limited 29% of the participants to search only for three problems.

Think-alouds were descriptions of mental processes which augmented the search logs and were very useful to analyze cognitive coordination and cognitive state shifts along the search process. Although some training was provided, over 20% of the participants did not frequently speak aloud or could not provide sufficient verbal data during their web search due to personal restrictions. For example, participants stated that “speaking cannot follow my thinking, quite stressful” (SP17), and “I cannot concentrate on reading when I have to speak” (SP38). One participant (SP5) even believed thinking aloud affected the search strategies a lot on the very open problem. Postsearch interviews were conducted as an option which relied on retrospective memory. However, think-alouds imposed an extra cognitive burden on the participants, diverting their concentration and resources to coordinate the extra cognitive activity of translating implicit thinking into explicit oral language. The impact of the extra cognitive burden on the web search was not considered in the derivation of the study results.

This study conducted the observations under conditions as close to real life as possible; participants posed information searching problems related to their real lives and subsequently evaluated the web search process and outcomes. However, the searching tasks ranged from the most straightforward to the extremely complicated one. The showcase of multitasking, cognitive coordination, and cognitive shifts should differ in the context of varied IPs. If the task attributes could have been studied, the scope of this study could have been increased.
Conclusions and Further Research

The article reveals important conclusions about cognitive coordination, as humans’ vital capability under conscious control is critical in supporting multitasking web searches and invoking the occurrence of shifts in cognition. The MCC model is the integration of web search and cognitive research, and is therefore very useful to enhance our understanding of the complexity of web search involving cognitive and CMs.

Further research directions include investigating: (a) the effect of the “memory imprinting” of cognitive experience obtained before, such as IP understanding on the continuing web search behaviors; (b) the influence of personal traits as well as IP attributes on the cognitive web search process, including users’ brain response of cognitive shifts and cognitive coordination behavior; and (c) a statistical test of the relationship identified in this study. For example, the correlation analysis was employed by previous web search studies.

Acknowledgments

Special thanks to the participants for their time. We thank Jill Slay and Jiuyong Li for their comments on the article and the anonymous reviewers for their comments and suggestions.

References


Appendix A

Presearch Questionnaire

1. Demographic variables:
   1.1. What is your age?
      _______ a. under 20 _______ b. 20–29 _______ c. 30–39
      _______ d. 40–49 _______ e. 50–59 _______ f. 60 and over

   1.2. Please indicate your gender: _______ Male _______ Female

   1.3. Your faculty/institute/division:

   1.4. Student status: _______a. Full time _______b. Part time

      Degree sought: ____________________________

2. Web using experience:

   2.1. How long have you been using the Web to look for information?
      _______a. One year–five years; _______b. Six years–ten years; _______c. Eleven years and over

   2.2. Which Web browser is used most frequently for information viewing? (e.g., Internet Explorer, Netscape, Mozilla, Maxthon, MyIE, and FireFox)

      ____________________________

   2.3. Which Web search engines do you use most frequently for information searching?

      ____________________________
3. Please describe your three information problems driving Web search in detail:

*Information Problem 1:*

__________________________________________________________________________________________________

*Information Problem 2:*

__________________________________________________________________________________________________

*Information Problem 3:*

__________________________________________________________________________________________________

4. For each information problem, is it a new problem area for you? Please tick in the corresponding box.

<table>
<thead>
<tr>
<th>Answer</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1. No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2. Yes. Is it precisely defined, or is it still fuzzy in any way?</td>
<td>Precisely defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Still fuzzy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. What is your current information problem stage for each information problem? Please tick in the corresponding box.

<table>
<thead>
<tr>
<th>Current information problem stage</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1. Problem Recognition—I am trying to determine whether or not the information problem I’m interested in is a real problem from the point of view of the discipline or area that interests me. I need a search so that I can discover whether others have identified the same issue as problematical.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2. Problem Definition—I have identified a real problem and now need to define it more closely or carefully so that I can determine how to approach the problem and how it relates to other information problems in the field. I need a search to help me define my research objectives.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.3. Problem Resolution—I am in the process of resolving the problem and now need information to enable me to proceed with and complete that work. The question deals with a particular problem that I need to resolve.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4. Problem Completion—I have effectively finished the work I was doing and I am either tying up loose ends, or finding out from related work how best to report my research or where best to report it.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. What is your current information seeking stage for each information problem? Please tick in the corresponding box.

<table>
<thead>
<tr>
<th>Current information seeking stage</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1. Collection—Having focused my problem I am now collecting specific relevant information problem.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2. Exploration—I am now identifying specific information sources that I think will be useful.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.3. Formulation—The information I have found has enabled me to form a clearer focus on the problem.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.4. Initiation—I have recognized that I need information at this stage of my work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5. Presentation—I am in the process of finishing the collection of information for this stage of my work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.6. Selection—I have identified the general area in which I need information.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Please rank (circle) your current specific personal or internal knowledge in relation to each information problem on the following 5-point Likert scale.

<table>
<thead>
<tr>
<th>Problem 1</th>
<th>Little specific knowledge</th>
<th>1—2—3—4—5</th>
<th>Considerable specific knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem 2</td>
<td>Little specific knowledge</td>
<td>1—2—3—4—5</td>
<td>Considerable specific knowledge</td>
</tr>
<tr>
<td>Problem 3</td>
<td>Little specific knowledge</td>
<td>1—2—3—4—5</td>
<td>Considerable specific knowledge</td>
</tr>
</tbody>
</table>

** END OF PRE-SEARCH QUESTIONNAIRE **

**THANK YOU**

APPENDIX B

Postsearch Questionnaire

1. Which Web search systems were employed in your current searches?

_________________________________________________________________________________________________

2.1. How did you order your information problems when searching on the Web? Please make the corresponding choices.

The first information problem you searched is:

_______a. Problem 1    _______b. Problem 2    _______c. Problem 3

The second information problem you searched is:

_______a. Problem 1    _______b. Problem 2    _______c. Problem 3

The third information problem you searched is:

_______a. Problem 1    _______b. Problem 2    _______c. Problem 3

2.2. Why did you order your three information problems in that way?

______________________________________________________________________________________________

3.1. How did you switch information problems from one to another during the search process?

______________________________________________________________________________________________

3.2. Why did you switch your information problems in that way?

______________________________________________________________________________________________

4.1. Was there any new information problem developed during your Web search?

No/Yes: ________________________________

4.2. If yes, what were they?

______________________________________________________________________________________________

4.3. What factors pushed you to generate new information problem(s) and thus deferred or suspended current information problem searching?

______________________________________________________________________________________________

5. Did any changes occur in your understanding of each information problem as result of search? Please indicate (circle) each on the following 5-point Likert scale.

<table>
<thead>
<tr>
<th>Problem 1</th>
<th>No changes in my understanding</th>
<th>1—2—3—4—5</th>
<th>Significant changes in my understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem 2</td>
<td>No changes in my understanding</td>
<td>1—2—3—4—5</td>
<td>Significant changes in my understanding</td>
</tr>
<tr>
<td>Problem 3</td>
<td>No changes in my understanding</td>
<td>1—2—3—4—5</td>
<td>Significant changes in my understanding</td>
</tr>
</tbody>
</table>

6. What is current information problem stage for each information problem? Please tick in the corresponding box.

<table>
<thead>
<tr>
<th>Current information problem stage</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1. Problem Recognition—I am trying to determine whether or not the information problem I’m interested in is a real problem from the point of view of the discipline or area that interests me.</td>
<td>Problem 1</td>
<td>Problem 2</td>
<td>Problem 3</td>
</tr>
</tbody>
</table>
6.2. **Problem Definition**—I have identified a real problem and now need to define it more closely or carefully so that I can determine how to approach the problem and how it relates to other information problems in the field.

6.3. **Problem Resolution**—I am in the process of resolving the problem and now need information to enable me to proceed with and complete that work.

6.4. **Problem Completion**—I have effectively finished the work I was doing and I am either tying up loose ends.

7. What is current information seeking stage for each information problem? Please tick in the corresponding box.

<table>
<thead>
<tr>
<th>Current information seeking stage</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7.1. Collection</strong>—Having focused my problem I am now collecting specific relevant information problem.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7.2. Exploration</strong>—I am now identifying specific information sources that I think will be useful.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7.3. Formulation</strong>—The information I have found has enabled me to form a clearer focus on the problem.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7.4. Initiation</strong>—I have recognized that I need information at this stage of my work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7.5. Presentation</strong>—I am in the process of finishing the collection of information for this stage of my work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7.6. Selection</strong>—I have identified the general area in which I need information.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Please rank (circle) your current specific personal or internal knowledge in relation to each information problem after searching on the following 5-point Likert scale.

| Problem 1 | Little specific knowledge | 1—2—3—4—5 | Considerable specific knowledge |
| Problem 2 | Little specific knowledge | 1—2—3—4—5 | Considerable specific knowledge |
| Problem 3 | Little specific knowledge | 1—2—3—4—5 | Considerable specific knowledge |

9. Please estimate (circle) the contribution the Web searching has made to the resolution of each information problem on the following 5-point Likert scale.

| Problem 1 | Nothing contributed | 1—2—3—4—5 | Substantial contributed |
| Problem 2 | Nothing contributed | 1—2—3—4—5 | Substantial contributed |
| Problem 3 | Nothing contributed | 1—2—3—4—5 | Substantial contributed |

**END OF POST-SEARCH QUESTIONNAIRE**

**THANK YOU**