Study of Multitasking, Cognitive Coordination and Cognitive Shifts in Web Search: Preliminary Findings

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ABSTRACT
This paper discusses users’ cognitive coordination processes and their shifts in cognition when multi-tasking across different information searching problems on the Web. Preliminary results are presented for an exploratory study investigating the nature and roles of multitasking and cognitive behaviors during 42 Web searches. The purpose of this study is two-fold: (1) to understand the nature of each process of multitasking, cognitive coordination and cognitive shifts within user–Web interaction; (2) to identify the relationship between multitasking, cognitive coordination and cognitive shifts during Web search. Multitasking as a prevalent behavior during Web search was achieved through task coordination. The task level coordination behavior was supported by cognitive coordination mechanisms including feedback, self-learning and regulating, and strategy coordination. Humans’ mental process of cognitive shifts occurred due to coordination behaviors during multitasking Web search. User–Web interaction appears more complicated than previously understood.

Keywords
Web search, multitasking, cognitive coordination, cognitive shifts, interactive information retrieval.

INTRODUCTION
Web search is a complex activity involving multitasking and coordinating behaviors between the tasks. At a basic level, this may involve executing multiple perceptual-motor actions concurrently, such as reviewing search results and clicking an associated link by using the mouse or keyboard. At an advanced level, this may involve interleaving the steps of many cognitive and interactive tasks, such as judging relevance while reformulating the query and starting a new-run of searching.

Studies on Web search behavior are concerned with how people search the Web including people’s affective and cognitive processes involved in Web search interactions. Efforts have been made on understanding elements and patterns of Web search (Hawk & Wang, 1999; Tauscher & Greenberg, 1997), and Web search models illustrating the dynamic interaction between information problem, user, and information environment and the iterative effect on users’ search strategies, processes and outcomes (Choo, Detlor & Turnbull, 2000; Ford, Miller & Moss, 2005; Hodkindon & Kiel, 2003; Wang, Hawk & Tenopir, 2000).

Recent research shows that users engage in multitasking information behavior during Web search episode. Spink, Ozmutlu and Ozmutlu (2002) found that multitasking Web searches are noticeable behaviors as one tenth of Excite users and one third of alltheWeb.com users conducted multitasking searches. Web users conduct information searching on multiple related or unrelated topics and switch among the topics. Multitasking search sessions with a broad variety of search topics are longer than regular search sessions in terms of queries per session and duration (Koshyman, Spink & Jansen, 2006). Spink, Park, Jansen and Pedersen (2006) conducted separate studies of two-query search sessions and three or more query search sessions on the AltaVista Web search engine. The degree of multitasking search and task switching was examined. They found that a high degree of multiple topics as well as frequent topic changes existed in both two-query sessions (81%) and three or more query sessions (91%). Multitasking was found to be a fundamental behavior in Web search.

Despite the growing body of studies on multitasking behavior, results were normally solicited from analysis of transaction logs and the exploration of Web users’ search terms and queries. Psychologists suggest that a multitasking process involves an individual allocation of one’s own scarce cognitive resources among several tasks and the moderating impact of task elements, task processes, and task resources on multiple-task performance (Iani & Wickens, 2004; Wickens, 1989). Multitasking research includes both task characteristics and coordination processes. The prior work on descriptive statistical reports of multiple search sessions, number of multiple topics and queries, and frequency of task switching are not fully enough to demonstrate the attributes of multitasking behavior during Web search.
The task coordination research concerns how people coordinate their activities to perform tasks, in particular, decision-making and problem-solving tasks (Waller, 1997). Du and Spink (2009) originally explored task coordination and cognitive coordination mechanisms during Web search. They propose that people perform and coordinate between the translation of their information problem(s), search term selection tasks, tactic and strategy tasks, search engine interaction tasks, and relevance judgments during Web search. Cognitive coordination allows users to trade off the dependences among multiple information tasks and the resources available. Smooth interactive IR must be a successful process of coordinating between multiple tasks. A further study is needed on how humans’ cognitive executive control processes establish priorities among multiple information tasks and allocate resources to them thus allowing efficient multiple-task performance during user–Web interactions.

Studies also report that users experience various shifts at information problem, search strategies and stages, and personal knowledge levels during Web search (Robbins, 2000; Santon, 2003; Xie, 2000). Cognitive shifting is a human capability to handle the demands of complex and often multiple tasks resulting from changes due to external forces (Spink & Dee, 2007). Cognitive shifting is an important research area for understanding the cognitive processes associated with Web search (Du & Spink, 2009). The existing research identified users’ cognitive shifts as the outcomes of Web search interactions measured before and after Web search (Spink & Dee, 2007). Few empirical studies have investigated the occurrence and nature of ongoing cognitive changes during user–Web interactions. It is worthy to note ongoing cognitive shifts in order for a better understanding of dynamic Web searches.

As reviewed, much research has been worked on Web search behavior, but little has examined the nature of and relationship between multitasking, cognitive coordination and cognitive shifts in the Web search context. Du and Spink (2009) reported results from a pilot study with two study participants where multitasking, cognitive coordination and cognitive shifts were found as important components of users’ Web search behavior. Web searchers allocate and coordinate cognitive and other resources among multiple tasks, and experience shifts in cognitive, problem, and knowledge states (Du & Spink, 2009).

The present article extends the prior pilot study results based on the empirical data from 42 study participants’ Web search interactions. The research questions which are addressed include: (1) what are characteristics of multitasking behavior during Web search? (2) What levels of cognitive coordination occur during Web search? (3) What types of cognitive shifts occur during Web search? (4) How do multitasking, cognitive coordination, and cognitive shifts interplay during Web search? The findings are significant for increasing the understanding of Web search behavior and developing theoretical Web search models, also provide implications for improving the design of IR systems and interfaces facilitating user–Web interaction.

**METHODOLOGY**

**Study Participants**

Forty-two postgraduate students (24 males and 18 females) from the Queensland University of Technology in Brisbane, Australia participated in this study from September to November in 2008 (Du, 2010). The students were from diverse programs including PhD, Masters, MBA, Graduate Diploma and Graduate Certificate across the disciplines of Science, Technology, Business, Engineering, Education, Creative Industries, and Health. The various backgrounds made study participants as heterogeneous as possible in their Web search interests and activities. Eighty-eight percent of the study participants have been using the Web for information searching for over six years.

**Information Searching Problem and Web Search System**

In order to better simulate Web search reality, the information searching problems were user-initiated rather than assigned by the researcher. The subsequent data collection and analysis relied on the context of information problems provided by the study participants. In the recruitment email, study participants were asked to prepare three information problems related to their individual everyday work or life and bring them to the study session. In the researcher’s laboratory, study participants were required to write down the descriptions of their three information problems on the pre-search questionnaire. The requirement to investigate three information problems allowed the researcher to analyze users’ multitasking behavior. Study participants were asked to conduct searches on their three planned information problems within one-hour searching period. There was no treatment or control on how the study participants interacted with the Web to find solutions to their information problems, including no restrictions on the selection of Web search systems.

**Data Collection Techniques and Analysis Methods**

The data were collected through multiple techniques, including pre- and post-search questionnaires, think-aloud protocols, observations, Web search logs, and post-search interviews. Think-aloud data and Web search logs were recorded by the screen-capture software Camtasia Studio concurrently. Amongst multiple data sources, the Web search logs and transcribed think-aloud data (called search-utterance segments) constituted principal sources of analysis in this study. The methods of verbal protocol analysis and content analysis based on the Grounded Theory approach were utilized to examine the nature of users’ multitasking, cognitive coordination and cognitive shifts behaviors through the observations of multitasking episode, cognitive coordination occurrences and types of cognitive shifts in the data.
Identification of Multitasking Episode
A multitasking episode was defined as descriptions of the behavioral variables including the ordering and switching between multiple information searching tasks, the generation of evolving information problems, and the conduction of multiple search sessions. One information problem searching occurred in a single Web search session. Multitasking data were identified through analysis of study participants’ post-search questionnaires and Web search logs. Each study participant was required to answer the following questions on the post-search questionnaire: (a) how and why did you order your multiple information problems? (b) How and why did you switch your information searching tasks from one to another? (c) Was there any evolving information problem generated during your Web searching? What were they? Study participants’ responses were considered as self-explanations of their recorded logs of multitasking behaviors. Web search logs were examined for the evidence of the study participants’ multiple search sessions as well as their answers to the above questions.

Identification of Cognitive Coordination Occurrence
Cognitive coordination occurrences were identified through the analysis of think-aloud transcripts and Web search logs, that is, verbal protocol analysis of the search-utterance segments. Each study participant was required to verbalize their thoughts, actions and underlying reasons at the same time as conducting the Web search. Study participants’ utterances related to the Web searching activities were transcribed onto the section of their search logs which recorded those activities. The transcripts and search logs were segmented into cognitive coordination occurrences. A cognitive coordination occurrence was demonstrated as iterative sequence behavior including information problems identification; search terms (re)selection and queries (re)formulation; system output in response to the search strategies; study participants’ utterances including relevance and magnitude judgment feedback, and sense-making process relating to the systems output; and study participants’ actions relating to the relevant items retrieved. Cognitive coordination occurrences were coded and classified into the three different levels that are reported in the Research Findings section.

Identification of Types of Cognitive Shifts
Cognitive shifts occur both during the searching process and after Web search. Cognitive shifts occurred as result of Web search interactions were identified mainly through the analysis of pre- and post-search questionnaires. Each study participant was asked to indicate their shifts on the 5-point Likert scale prior to and at the end of Web search, respectively. A cognitive shift was indicated as a change of perception in terms of information problem understanding, information problem stage, information seeking stage, personal knowledge, and contribution to the information problem resolution before and after Web search. Content analysis and descriptive statistics revealed study participants’ shifts in cognition. Types of cognitive shifts experienced during the searching process were captured by the Web search logs. The analysis of the search-utterance segments provided the details of study participants’ cognitive states and changes between the states which were identified via cue words in study participants’ utterances.

RESEARCH FINDINGS
Multitasking Behavior during Web Search
The findings are based on the analysis of the 42 user–Web interactions. Multiple information problems consisted of original information problems (OIP) which initiated study participants’ Web search and evolving information problems (EIP) which were generated during the searching process. The searching tasks were switched between multiple information problems.

Factors Affecting Multiple Information Problems Search Ordering
The study participants’ OIPs (i.e. each three information problems written down on the pre-search questionnaire) covered a wide range of topic areas, including thesis research, course assignment, jobs & careers, travel, news, food & entertaining, technology, finance information, lifestyle, favorite music & movies, online shopping, sports information, online gaming, and housing rentals. The planned search was either for three related (31%) or unrelated (69%) topics. Study participants made decisions on the order of their multiple information problems searching prior to the Web search based on several perceived factors. The results show that problem importance level—from the most important to the least important (29%), randomness—in a random order (26%), and ease of finding information—from the easiest to the hardest (24%) were the three major factors in determining non-assigned information problems search ordering.

Our research meets Spink, Park and Koshman’s (2006) call for further research into information problem prioritization and ordering in non-assigned problem environments. Personal interest and problem familiarity mainly affecting assigned information problems ordering (Spink, Park & Koshman, 2006) were not verified as major factors influencing non-assigned information problems ordering.

Evolving Information Problem Generated during the Successive Web Searches
In addition to the planned three OIPs, over 70% of the study participants developed EIPs during the successive Web search. The number of EIPs per study participant ranged from zero to eight, with a mean of 2.3. Compared with OIPs, EIPs were represented as changed problems or totally new ones. Evolving information problems were detected by topic shifts. The following is an example of the planned OIPs and generated EIPs during Web search (Table 1).
Thirty, including identification of (consisting of more search sessions. The 42 study sessions were applied into a Web Maps, accordingly received result sample of task switch, made context. The reasons for ing task switching, and total, participants conducted 315 search sessions in total, with a number of search sessions from 3 to 16, with 26% reporting the conduction of 10 or more search sessions. The 42 study participants conducted 315 search sessions in total, with a mean number of 7.5 per study participant. The reasons for conducting multiple Web search sessions were probably due to the current information problem evolving or changing. As for a Web searching episode involving multiple Web search sessions with multiple information problems, the number of switched information searching problems ranged from three to twelve, the number of submitted queries varied from four to thirty-nine, and the number of employed Web search systems ranged from one to ten. The results provide us with a comprehensive picture of evolving search. What being evolved or changed was not merely the query but the searching context which was from one information problem scenario to another. This is more complex than previously understood.

### Levels of Cognitive Coordination

The occurrences of cognitive coordination were analyzed, coded and finally classified into three levels. They were task coordination level, coordination mechanism level, and strategy coordination level.

#### Level One: Information Task Coordination

Task coordination was represented as the coordination between the information tasks, including identification of OIPs, generation of EIPs, searching task switching, and windows/tabs browsing. There were 280 task coordination occurrences identified during the 42 searches, representing only 5% of the total coordination occurrences, with a mean of 6.7 per search. Detailed below is an example of task coordination occurrence.

Study Participant 15 identified the second OIP (OIP2) of looking for caravan parks around Melbourne including their names and prices. Other forms of coordination mechanism included windows/tabs browsing. There were 280 coordination occurrences identified during the 42 searches, representing 61% of the total coordination occurrences.

#### Level Two: Cognitive Coordination Mechanism

The cognitive coordination mechanism was the underlying system supporting information task coordination. There were 3,164 coordination mechanism occurrences identified during the 42 searches, representing 61% of the total coordination occurrences. The results indicate that coordination mechanism was a significant feature of each of the 42 searches. Coordination mechanism involved a series of cognitive processing activities – most of these were content relevance feedback (36%) of making relevance judgments on the returned results, and self-learning and regulating process (43%) of making sense of the gathered information. Other forms of coordination mechanism included tactical review feedback (14%) which made strategy-related adjustments based on the retrieved results, magnitude feedback (5%) that made judgments on the size of output, and term relevance feedback (2%) consisting of users identifying a term (terms) within the retrieved results.

The results show that those three forms of feedback

### Table 1. An example of the planned OIPs and generated EIPs.

<table>
<thead>
<tr>
<th>Study Participant 15</th>
<th>OIP1. Looking for the 10 schools, private or state, in radius 30 minutes drive from my house (Eight Mile Plains).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OIP2. Looking for caravan parks around Melbourne and those are in the way to Melbourne: name and price.</td>
</tr>
<tr>
<td></td>
<td>OIP3. Looking for the cheapest accommodation and flight to New Zealand on the mid of January, for 2 weeks.</td>
</tr>
<tr>
<td></td>
<td>EIP1. Looking for the surrounding suburbs around my home in Google Maps.</td>
</tr>
<tr>
<td></td>
<td>EIP2. Information on the distance between a parking place and Melbourne.</td>
</tr>
<tr>
<td></td>
<td>EIP3. Looking for the cheapest flight from Brisbane to Auckland.</td>
</tr>
<tr>
<td></td>
<td>EIP4. Looking for the cheapest accommodation in Auckland CBD.</td>
</tr>
<tr>
<td></td>
<td>EIP5. Information on the area in Auckland.</td>
</tr>
</tbody>
</table>

#### Figure 1. An example of searching tasks switching.

**Multiple Web Search Sessions**

A Web search session had four basic elements: a particular information problem, the queries sequences, the selected Web search systems, and the opened windows/tabs. Multiple Web search sessions were applied into a Web search episode during which multiple information problems searching occurred.

Study participants reported a wide variation in terms of the number of search sessions from 3 to 16, with 26% reporting the conduction of 10 or more search sessions. The 42 study participants conducted 315 search sessions in total, with a mean number of 7.5 per study participant. The reasons for conducting multiple Web search sessions were probably due to the current information problem evolving or changing.
mechanism seldom occurred. Detailed below is an example of coordination mechanism occurrence.

Study Participant 15 made content relevance feedbacks - judged the relevance of the information returned by the Google Maps. For example, he/she commented, “It seems that it doesn’t come up appropriately”, and “Ok, good, that’s (the) one here”. The participant made important self-learning and regulating judgments - he/she learnt the information appeared on the webpage against his/her searching aim and adjusted strategies. For instance, the participant stated, “But actually I found something wrong here, the link I just opened up is very far away”, and “It’s eight mile plains state school. I need its website”. The participant also made a few tactical review feedbacks - for example, “Then I can go back to Google again, and just find private schools within the scope of these suburbs” and magnitude feedbacks - for example, “Lots of results coming up, I need to check them”. The above coordination mechanisms are underlying determinants driving task level coordination behavior between multiple information searching tasks, for example, switching from the searching task on OIP2 to EIP2.

**Level Three: Cognitive Strategy Coordination**

Strategy coordination was considered as a strategic plan for solving information problems within the resources available. It was represented as two sorts of strategies: problem specific strategy and global strategy. Problem specific strategy was viewed as the collection of tactics on usable Web searching tools for each information problem solving, including the selection of Web search systems, the adoption of search queries, the reviewing of results set (pages) as well as the saving of relevant results. Global strategy was an overall plan guiding the whole searching process which was presented as users’ decisions on the allocation of the searching time between multiple information problems. Time allocation was not found as a random behavior but a conscious strategy. There were 1,756 strategy coordination occurrences identified during the 42 searches, representing 34% of the total coordination occurrences. Detailed below is an example of strategy coordination occurrence.

For a particular information problem, Study Participant 15 made problem specific strategies - he/she selected Google as the search system, (re)formulated four search queries for EIP2, copied the contact details and pasted/saved them to a word document. Regarding the global strategies, the participant moved to the OIP3 when the searching on OIP2 was completed “I think it’s done, I still got 20 minutes left”.

**Types of Cognitive Shifts**

**Holistic Cognitive Shifts**

Measured before and after Web search, holistic cognitive shifts were represented as the changes of users’ perception over an information problem with respect to information problem understanding, information problem and seeking stages as well as personal knowledge and contribution to the information problem resolution. The results support Spink and Dee’s (2007) findings that study participants reported tendencies of holistic shifts: forward, backward, and no shift with respect to information problem understanding and knowledge contribution. Different study participants reported different degrees of the shifts. In most situations, they experienced forward shifting. The results show that 67% of the study participants reported the Web search interaction contributed to the resolution of their information problems.

**Cognitive State Shifts**

Unlike previous studies which are limited to the shifts at holistic cognition level measured before and after Web search, dynamic shifts at users’ cognitive state level occurred during the searching process were investigated in this study. State shifts were the cognitive changes in focus of the interaction between a user and a Web search system with respect to the users’ cognitive states. State shifts reflect how users move from one cognitive state to another during the interactions with Web search systems.

Five types of cognitive states were identified, including topic, strategy, evaluation, view and overview, with each standing for five distinct phases in the Web search process. The most experienced cognitive states were strategy, evaluation, and view. The three states formed more than 90% of the total cognitive states. As such, most shifts occurred between the states of strategy, evaluation, and view. Study participants recurrently diverted their attention/cognitive state from the search strategy adoption to evaluation of the upcoming search results, then to the examination/view on the opened Webpage. The findings indicated that the majority of foci dealt with input and output from the IR system.

**DISCUSSION AND CONCLUSIONS**

**Interplay between Multitasking, Cognitive Coordination and Cognitive Shifts**

Multitasking behavior during Web search was characterized as a two-dimensional activity. The first dimension referred to multiple information problems searching by task switching. The second dimension referred to multiple Web search sessions. Multiple Web search sessions were composed of multiple queries, multiple search systems, and multiple opened windows/tabs for more than one information problem searching. The investigations are significant for the development of multiple search sessions model. Evolving information problems during Web search were explored. Study participants switched their searching tasks between original information problems searching and evolving information problems searching according to the task coordination principle. Multitasking during Web search was achieved through task coordination behavior.

The task level coordination was controlled by humans’ cognitive level coordination mechanism including feedback
mechanisms and various strategies. During the searching process, study participants’ cognitive states shifted along with the adoption of coordination controls. At the end of Web search, study participants’ holistic perceptions on their information problems understanding and knowledge contributions were changed. The results provide a comprehensive understanding of cognitive shifts both during the searching process and as the outcomes of Web search.

This study explores multitasking, cognitive coordination, and cognitive shifts as an interplay structure to move through users’ Web search process. The findings theoretically underpin interactive Web search studies. Users’ multitasking, task switching and task coordination is little understood or supported by current search technologies. The results can be used as a theoretical base to design Web search systems that support smooth multitasking Web searches involving lots of cognitive efforts on the part of users. This paper presents the preliminary results of the study about the nature of each process of multitasking, cognitive coordination and cognitive shifts within user–Web interactions. A model illustrating the relationship between multitasking, cognitive coordination and cognitive shifts during Web search and the empirical implications for IR system design will be reported in forthcoming papers.

REFERENCES