Web Search as Multitasking, Cognitive Coordination, and Cognitive Shifts

Dr Jia Tina Du

School of Computer and Information Science
University of South Australia
Introduction

- Research Background

- Current Research Projects

Research Background

- Research focus – Web search, interactive information retrieval and information behaviour.
- PhD (Information Science) awarded in June 2010 from QUT
- Principal Supervisor of two PhD students and Associate Supervisor of one PhD student
- Publications 29+
Some Current Research Projects

- Exploring behaviours of information seeking, information judgments, information use and sharing in the workplace
  Supported by UniSA Division of ITEE Early Career Research Development Grant (2010-2011, 10/ECNA-01)

- Assessing the impact of personalisation on users interactions with search engines
  Supported by UniSA Division of ITEE Early Career Research Development Grant (2011-2012, 12/ECNA-09)
Web Search as Multitasking, Cognitive Coordination, and Cognitive Shifts

- Related studies
  - Web search
  - Multitasking behaviour
  - Coordination
  - Cognitive shifts
Web search

- Web searching as dynamic and iterative interaction between users, information tasks and Web search systems.

- Web search models (e.g. Choo et al., 2000; Ford et al., 2001, 2005; Wang et al., 2000):
  - illustrating dynamic interactions between information problem, user, and the Web,
  - showing users’ search patterns, sequences and search strategies during user-Web interaction,
  - Web search task characteristics, user intent and individual differences.
● Limitations of existing Web search models

- few examine the dynamic cognitive changes which occur during Web search

- the impact of these changes on Web search strategies

- based on the assumption that users are engaging in a single Web search session on a single topic.
An increasing number of recent studies demonstrate that people engage in multiple Web search sessions on multiple topics.

The increasing understanding of Web searching behaviour is significant to the development of Web search models and design of Web technologies.
Multitasking behaviour

- Multitasking is the human ability to handle the demands of multiple tasks by task switching (Lee & Taatgen, 2002).

- Multiple task situations are faced frequently in daily life.

- Task switching is an important element of multitasking. Multitasking is considered as switching behaviour from one task to another in rapid succession (Monsell, 2003).

- Cognitive executive control systems govern processes including the selection, initiation, execution, and termination of each task (Rubinstein, 2001).
Web search as multitasking

- Studies show multitasking and information task switching by information retrieval (IR) system and Web users (Spink et al., 2002, 2006).

- Studies with Excite, AlltheWeb.com, Alta Vista, Vivisimo and Dogpile Web query data (Ozmutlu et al., 2003; Koshman et al., 2006).

- Multitasking and task switching are believed to be important Web search behaviours.
Some conclusions:

- Users may pool together with more than one related or unrelated topics when searching on the Web, and switch between the searching on these topics.

- Web search as a multitasking process that often includes switching between multiple topics within single or multiple Web search sessions.

- Current investigations focus on multiple search topics and ordering between the topics.

- Research has paid little attention to exploring the cognitive aspects of multitasking and models of multitasking in the Web search context.
Multitasking research includes both task characteristics and coordination processes (Wickens, 1989).

Multitasking behaviour is conceptualized as a binding process that works with human coordination behaviours.

The task coordination research concerns how people coordinate their activities to perform tasks, in particular, decision-making and problem-solving tasks (Waller, 1997).
Coordination viewpoint

- Multitasking processes involve a person’s allocation of his/her own scarce cognitive resources among several tasks (Iani & Wickens, 2004).

- People may coordinate the translation of their information problem(s) by performing
  - search term selection tasks,
  - tactic and strategy tasks,
  - search engine interaction tasks, and
  - relevance judgments
Coordination

- People could consciously trade off performing dual tasks stemmed from their coordination capability (Wickens & Gopher, 1977).

- Coordination is the process of managing dependencies among activities or conflicts between goals, tasks, and resources of various agents (Crowston, 1997).

- Cognitive coordination at different levels enables humans to manage various dependencies among tasks and resources available (Miyata & Norman, 1986).
Coordination behaviour in IR and Web search

- In IR models, coordination is also understood as modulation among subsystems, including planning, agenda, user modeling, request modeling, and I/O requests (Belkin et al., 1987).

- Ma (2008) Interactive IR Coordination Model

- Park (2008) Prioritising and Coordinating Information Behaviour Model in Web Information Seeking and Retrieval

- The identification of cognitive coordination may be helpful in understanding the process of user-Web interaction.
Cognitive shifts

- Cognitive shifting is a higher mental process as it relies on interaction between the brain’s internal mechanisms and external forces (Simon, 1981).

- Xie (2000) three levels of shifts in users’ attempts to achieve searching goals

- Robins (2000) information problem shifts

- Santon (2003) search stages shifts
Cognitive shifts (cont)

- Users may experience some type of shift in cognitive, problem and knowledge states (Du & Spink, 2009; Spink, 2002).
- Little empirical investigation of the types and frequency of shifts in cognition during user–Web interactions.
- Limited studies have investigated the occurrence and nature of undergoing cognitive changes as users search on the Web.
Du’s study aims

- Examine how users cognitively coordinate Web searches when multitasking across different information problems
- Model the relationship between multitasking, cognitive coordination, and cognitive shifts during Web searching
Research Questions

- How do users conduct their Web searches on multiple information problems?
- What levels of cognitive coordination occur during Web search?
- What types of cognitive shifts occur during Web search?
- How do multitasking, cognitive shifts and cognitive coordination interplay during Web search?
Research Design – Data Collection

- A combination of data gathering techniques
  - pre- and post- search questionnaires,
  - think-aloud protocols,
  - search logs,
  - observations, and
  - semi-structured interviews

- 42 postgraduate students who conducted 315 Web search sessions with 221 information problems.
Data Collection

- Search query vs. information problem
- Three original information problems (OIP) from each study participant
- In total 126 OIPs (42*3) across 15 various topic areas were observed over the Web searches, amounting to approximately 35 hours.
Data analysis

- The search logs and think-aloud audio data were recorded by Camtasia Studio screen software.

- The analysis unit was each information search problem instead of search query.

- Web search process as flowchart

- Qualitative content analysis and open coding based on the Grounded Theory approach carried out.
Key results

- Multitasking was found to be more complex than previously portrayed in Web search models.

- Multitasking during Web search was represented as
  - multiple information problems search ordering,
  - evolving information problems development,
  - information problem searching task switching,
  - multiple Web search sessions.
Multiple information problems ordering

- Study participants prioritized the searching order among three OIPs.

- Factors affecting information problems search ordering
  - Problem importance level (high-to-low) 29%
  - Randomness 26%
  - Ease of finding information on the Web (high-to-low) 24%
  - Task logic
  - Problem urgency level
  - Task interest
  - Problem familiarity level
  - Future usefulness

- Multiple factors applied (over 40%)
Evolving information problem (EIP)

- An EIP was detected by topic shifts. The total number of EIPs was 95.

- Compared to an OIP, an EIP was represented as changed or totally new problems.

- Over 70% of the study participants generated EIPs
  - 17% generated one evolving information problem
  - 12% generated two evolving information problems
  - Over 40% generated three or more evolving information problems

- The number of evolving information problems per study participant ranged from zero to eight.
Information searching tasks switching

- Search tasks switch between 221 information problems (126 OIPs + 95 EIPs), approximately five information problems on average.

- Types of Information Searching Task
  - Searching on an Original Information Problem (SOIP)
  - Searching on an Evolving Information Problem (SEIP)

- Information task switching as a process of ceasing to search information on one task and proceeding with another information task.
Task Switching Pattern

- **Pattern A (21%)** SP1:
  - SOIP1 → SOIP2 → SOIP3

- **Pattern B (7%)** SP6:
  - SOIP1 → SOIP2 → SOIP3 → SOIP1 → SOIP2

- **Pattern C (29%)** SP10:
  - SOIP1 → SEIP1 → SOIP2 → SOIP3 → SEIP2 → SOIP3

- **Pattern D (43%)** SP13:
  - SOIP1 → SOIP2 → SEIP1 → SOIP2 → SEIP2 → SEIP3 → SOIP3 → SEIP4 → SOIP3
## Sequential multitasking and parallel multitasking

<table>
<thead>
<tr>
<th>Out of 42 searches</th>
<th>No.</th>
<th>%</th>
<th>Mean time per task</th>
<th>Description</th>
<th>Example</th>
<th>Reasons for task switching (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential multitasking</td>
<td>13</td>
<td>31</td>
<td>12min</td>
<td>Task switching from searching on one information problem to another and without iteration.</td>
<td>① SOIP1 → ② SOIP2 → ③ SEIP1 → ⑧ SOIP3 (SP37)</td>
<td>Coordination mechanism (45) Strategy coordination (17) Interest shift (0) Visual cues (0)</td>
</tr>
<tr>
<td>Parallel multitasking</td>
<td>29</td>
<td>69</td>
<td>8min</td>
<td>Task switching from searching on one information problem to another and jumping back and forth.</td>
<td>① SOIP1 → ② SOIP2 → ④ SEIP2 → ⑥ SEIP3 → ⑧ SOIP3 (SP13)</td>
<td>Coordination mechanism (95) Strategy coordination (45) Interest shift (5) Visual cues (5)</td>
</tr>
</tbody>
</table>
Multiple Web search sessions

- A Web search session is regarded as a period devoted to a particular Web information problem searching.

- Elements in a Web search session:
  - the queries sequences
  - the selected Web search systems
  - the opened windows-tabs

- Number of search sessions from 3 to 16, with 26% reporting having conducted 10 or more search sessions. Mean number: 7.5.
Summary: characteristics of multitasking behaviour

<table>
<thead>
<tr>
<th>Multitasking search sessions</th>
<th>Total</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>OIP identification</td>
<td>126</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>EIP generation</td>
<td>95</td>
<td>0</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Total information problems (OIP+EIP)</td>
<td>221</td>
<td>3</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Searching task switches</td>
<td>275</td>
<td>2</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Search query</td>
<td>742</td>
<td>4</td>
<td>39</td>
<td>18</td>
</tr>
<tr>
<td>Search system</td>
<td>75</td>
<td>1</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Windows/tabs browsing</td>
<td>730</td>
<td>3</td>
<td>39</td>
<td>17</td>
</tr>
</tbody>
</table>
Cognitive coordination behaviour in multitasking Web search

- **Cognitive coordination** allows humans to manage dependences among information tasks and resources available (Du & Spink, 2011).

- Cognitive coordination occurrence involves:
  - Information problems identification;
  - Search terms (re)selection and queries (re)formulation;
  - System output in response to the search strategies;
  - Relevance and magnitude judgment feedback, and sense-making process relating to the system output;
  - Strategies and actions relating to the relevant items retrieved.
## Cognitive coordination occurrence

<table>
<thead>
<tr>
<th>Level of cognitive coordination</th>
<th>Number of searches (out of 42)</th>
<th>Number of occurrences</th>
<th>%</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level one:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task coordination (TC)</td>
<td>IT</td>
<td>42</td>
<td>280</td>
<td>5</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Level two:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordination mechanism (CM)</td>
<td>TRF</td>
<td>25</td>
<td>78</td>
<td>1.5</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>CRF</td>
<td>42</td>
<td>1,146</td>
<td>22</td>
<td>27.3</td>
</tr>
<tr>
<td></td>
<td>MF</td>
<td>34</td>
<td>148</td>
<td>3</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>TCF</td>
<td>42</td>
<td>446</td>
<td>8.5</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>SLR</td>
<td>42</td>
<td>1,346</td>
<td>26</td>
<td>32.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3,164</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td><strong>Level three:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy coordination (SC)</td>
<td>PSS</td>
<td>42</td>
<td>1,614</td>
<td>31</td>
<td>38.4</td>
</tr>
<tr>
<td></td>
<td>GS</td>
<td>42</td>
<td>142</td>
<td>3</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,756</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>5,200</td>
<td>100</td>
<td>124</td>
</tr>
</tbody>
</table>
Level One: Information Task (IT) Coordination (TC)

- OIP identification
  
  [“The second problem I'm trying to find out the (medical) function of shark cartilage.”]

- EIP generation
  
  [“I met a word "angiogenesis" in this article. What is angiogenesis? I need to look it up in the dictionary before continuing the current problem searching.”]

- Problem searching task switching
  
  [“Now move on to the third problem.”]

- Windows/tabs browsing
Level Two: Cognitive Coordination Mechanism (CM)

- Term Relevance Feedback (TRF)
- Content Relevance Feedback (CRF)
  - [“Yes, here we go, this one is good (followed by clicking on the 3rd entry link)”].
- Magnitude Feedback (MF)
- Tactical Review Feedback (TCF)
  - Decision on changing a search keyword
  - Decision on changing information source
- Self-learning and Regulating (SLR)
  - [“This is a high quality research, quite good. So shark cartilage is useful to the treatment of arthritis.”]
Level Three: Cognitive Strategy Coordination (SC)

- Strategic plan for solving information problems within the resources available: the usable Web searching tools as well as the limited timeframe.

- Problem Specific Strategy (PSS)
  - Web search systems selection
  - Search query formulation
  - Next result page review
  - Relevant results saving

- Global Strategy (GS)
  - Searching duration
  - Time allocation
Summary: Cognitive coordination in multitasking Web search

- The occurrence of cognitive coordination played an active role in multitasking and task switching activities.

- Multitasking was supported and underpinned by cognitive coordination mechanisms and strategy coordination.

- *Coordination mechanism* involved a conscious reasoning and judging process – most of these were content relevance feedback (36%), and self-learning and regulating process (43%) of making sense of the gathered information.
Summary (cont)

- **Coordination mechanism** as the most important reason for users’ task switching behavior (45% for sequential multitasking and 95% for parallel multitasking).

- Multitasking Web search was cognitively constructed as users learned with information attainment during the process.
  - “I have found enough related information, I’d move on to next information problem”
  - “I did not think the information was useful, I might change the keywords”
Summary (cont)

- Strategy coordination, including problem specific strategy and global strategy, was viewed as the second most important reason for users’ task switching behaviour (17% for sequential multitasking and 45% for parallel multitasking).

- Other two minor reasons for parallel multitasking and task switching were interest shift (5%) and visual cues (5%).
Cognitive Shifts during Web Searching

- During Web search, study participants also experienced various cognitive shifts.

- Two categories of cognitive shifts
  
  - *holistic shifts*: the cognitive changes on the information problems which were measured before and after Web searching.
  
  - *state shifts*: the cognitive changes in focus of the interactions between a user and a Web search system with respect to the user’s cognitive states.
Holistic shifts

- **Shifts in Information Problem Understanding**
- **Shifts in Information Problem Stage**
  - 50% “positive”, 40% “same”, 10% “negative”
- **Shifts in Information Seeking Stage**
  - 38% “forward”, 35% “backward”, 17% “same”, 10% “multiple”
- **Shifts in Personal Knowledge**
  - over 60% “positive”, 31% “same”, 7% “negative”
- **Contribution to the Information Problem Resolution**
  - 67% “significant contributions”
State shifts

- Cognitive state was verified to be constantly transformable and the shifts occurred frequently.

- State shifts reflect how study participants moved between different cognitive states during the searching interactions.

- Most shifts occurred between the states of strategy (STR), evaluation (EVA), and view (VIE).

<table>
<thead>
<tr>
<th>Type of cognitive state</th>
<th>Number</th>
<th>%</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOP (Topic)</td>
<td>281</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>EVA (Evaluation)</td>
<td>1366</td>
<td>26</td>
<td>33</td>
</tr>
<tr>
<td>STR (Strategy)</td>
<td>2053</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>VIE (View)</td>
<td>1348</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>OVE (Overview)</td>
<td>142</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>5159</td>
<td>100</td>
<td>124</td>
</tr>
</tbody>
</table>
Multitasking, Cognitive Coordination and Cognitive Shifts (MCC) Relationship Model

- Web searching as a dynamic interaction between users, their information problems, and Web search systems.

- Information problems ordering, evolving information problems generation, searching task switching, task and mental coordinating occur, and at deeper level, cognitive shifts take place.

- The explicit task level coordination is closely linked to multitasking behaviour.
MCC model

- The implicit mechanism and strategy levels coordination guide and support the task coordination processes, especially for the development of evolving information problems and searching tasks switching.

- The occurrence of coordination mechanisms directly results in the shifts of cognitive states which further affect users’ holistic shifts in information problem understanding and knowledge contribution.
MCC Model

Web Search Interaction

- Web Search Problems
- System Returned Results

Web Search System ↔ User

External Force:
- Individual Differences
- IP Attributes

Cognitive Shifts ↔ Cognitive Coordination ↔ Multitasking

Brain's Response
- Holistic Shifts
- State Shifts

Level 1: Task Coordination
- Task Switching:
  - OIP Identification and Searching
  - EIP Generation and Searching
  - Serendipity Browsing
- Multiple Web Search Session
- Windows/Tabs Browsing

Level 2: Coordination Mechanism
Level 3: Strategy Coordination
Further Research

- Investigating the influence of personal traits as well as search tasks attributes on the multitasking web search process.

- Implications for Web search practice and search system design by understanding multitasking and coordination processes during user–Web interactions.
Further Research

- The effect of the “memory imprinting” of cognitive experience obtained before, such as information problem understanding on the continuing Web search behaviors.

- The nature and occurrence of multiple Web search sessions and the development of multiple Web search sessions model.
References


QUESTIONS?

Thank You