Effect of Cognitive and Problem Solving Style on Internet Search:
A Framework of User-Oriented Evaluation

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This paper presents a user-oriented evaluation method to compare the usability of Internet search tools. Participants will be pre-tested for cognitive and problem solving style. The subjects will be given three sets of tasks to perform in controlled conditions. Participant will rate the usability of each search tools based on relevance and satisfaction. A framework of user-oriented evaluation on Internet search tools is proposed in this study. The ultimate aim of the research is to contribute to the knowledge concerning individual differences and information retrieval technology. In particular we hope to get a better understanding of which presentation structures and user interface attributes work best and why.

Keywords: Human Factor, Cognitive style, Problem Solving style, Internet Search, Usability

1. Introduction

Searching for information through the Internet browser is widely used by different level users. Currently, the Internet search tools are becoming more complex and even more frustrating for users. Extensive research had been carried out to measure each Internet search tools performance and interface design. Most of these findings were not based on actual tests and measurements. (Lawrence & Giles, 1998; Tegenbos & Nieuwenhuysen, 1997; Chu & Rosenthal, 1996; Ding & Marchionini; 1996; Barker, 1998). However, most of the researchers rather than users make relevance judgements on the Internet search tools (Su & Chen, 1999). Research investigating how different users use a search tool and identifying the factors affecting the usage is important to help developing user-friendlier search tool (Wang & Tenopir, 1998). Previous studies of searching behavior suggest that differences in individuals search strategies; effectiveness of searches and the satisfaction with the result of searches are significantly linked to the differences in cognitive style (Ford et al, 1994; Nahl & Tenopir, 1996; Hong, 1999). This study aims to examine such findings in the context of Internet searching tools.

This study proposed to find how the users use the Internet search tools when searching information and how the users' psychological factors including cognitive and problem solving styles influences the searching patterns. Besides that, possible effects of type of search tasks will be investigated too. We will look into the possibility of involving users as evaluator on evaluating the efficiency and effectiveness of Internet search tools. In this paper, we will try to look for the following question:

• What is the effect of user's cognitive styles on the information search strategies on the Internet search tools?
• What is the effect of user’s problem solving style on the information search strategies on the Internet search tools?
• Do types of search task influence the user's information search performance and strategies?
• How well does Internet search tools perform from end-user judgements?
• Do users perceive interface design to be important when using Internet search tools?
• What kinds of interfaces for search engines or outputs provide maximum interaction between the system and the user?

In section 2, we discuss the type of search tools available on the Internet, individual differences and usability. In section 3, we review the related studies in the past. Our framework of experimental design is presented in Section 4. Summary and conclusion are presented in Section 5.

2. Definition of Terms
2.1 Internet Search Tools Differences
Internet search tools have been divided into different types based on their unique interface and services they provided over the Internet. We have identified three types: Individual search engine, Meta-search engine, and Portal.

2.1.1 Individual Search Engine (ISE)
Search engine is a program that searches through some dataset. Individual search engine run search algorithms based on user-input text expressions in their database. It presents a simple input textbox and a push button on the search page. The interface looks simple and easy to use. Users will have to formulate their query using appropriate search language like keywords and/or phrases with Boolean operator. They can also use parentheses and standard predicate calculus precedence to make a precise and unambiguous query. Then users will have to search through a set of results. The simple result page will display top 10 result retrieved from their indexed database. It does not have any other features on the result page. These engines will have a tendency to retrieve more duplicates, linkrots and plagued by low precision.

2.1.2 Portal (P)
Portal is a doorway, an entrance or a gate, especially one that is large and imposing. Portal is a new term, generally synonymous with gateway, for a World Wide Web site that is or proposes to be a major starting site for users when they get connected to the Web or that users tend to visit as an anchor site. Typical services offered by portal include a directory of Web sites, a facility to search for other sites, news, weather information, e-mail, stock quotes, phone, map information, and a community forum. Most of them provide user with too many option and feature and the interface
looks a bit cluttered. The reason is that they want to keep their users surfing inside their portal. Sometimes users do not even know where and how to search. Users may start their search using simple search textbox or using advanced search. The result page will provide many refinement features to help the user to narrow down their search like category matches, related search and multimedia. They even can begin their search through directory services. They may end-up frustrated and give-up when they cannot find any information (White & Iivonen, 1999).

2.1.3 Meta Search Engine (MSE)

Meta-search engine allows a user to submit a query to several different search engines for searching all at once. For this paper, the focus of the meta-search engine is browser add-on search tools. Add-on is one thing added as a supplement to another, especially a component that increases the capability of the system to which it is added. Copernic 2000, Web Ferret, Beeline and Quest 99 are among the browser add-on search tools. Since it has its own interface, users need to switch between two windows (web browser and meta search engine) when searching for information. Results are merged with duplicates and linkrots (dead links) removed. However, it may takes longer time to process user query. Navigation between browsers and add-on tools need to be considered also.

2.2 Individual Differences

It seems reasonable to argue that different individual will have different strategies when processing information. We will look into cognitive and problem solving style in individual differences.

2.2.1 Cognitive Style

Cognitive style is known as a tendency for an individual consistently to adopt a particular type of strategy. Cognitive style also refers to a manner of moving toward a goal and a characteristics way of experiencing or acting. It is the characteristic way in which the individual organizes and process information. Cognitive style can be measured in several different dimensions. In this study, cognitive styles as field dependence/field independence dimensions will be used.

Field Dependence/Field Independence

Witkin, Moore, Goodenough and Cox (1977) characterized field independent learners as making more use of mediational processes such as analyzing and structuring, adopting an active, hypothesis testing role in learning, less dominated by the most obvious or salient cues in learning and operating more from internally defined foals and reinforcements and thus more likely to be motivated by intrinsic or task oriented forms of motivation. On the other hand, field dependent learners are less effective users of mediational process, adopting a passive spectator role in learning, more dominated by salient cues in learning, and better at learning and remembering information having social relevance or content.
2.2.2 Problem Solving Styles

Problem solving can be defined as a goal oriented sequence of cognitive operation. The problem solving process comprises cognition as well as emotion and behavior. Skills of problem solving include the ability to search for information, to analyze situations for the purpose of identifying the problem in order to generate alternative courses of action, to weigh alternative courses of action with respect to desired or anticipated outcomes, to select and implement an appropriate plan of action and to evaluate the outcome with reference to the initial problem. As the term "problem" itself has different facets, there appears to be several aspects of problem solving process, among them are cognitive problem solving, personal problem solving and social problem solving. Problem solving style in this study is defined as a tendency to respond in a certain way while addressing problems and not as the steps employed in actually solving problem. Two problem-solving styles defined in this study are emotion-focused and problem focussed coping style (Heppner, 1988).

Emotion Focussed/Problem Focussed Coping Style

Individuals with an emotion focussed coping style tend to make themselves feel better about a problematic situation without changing the problem itself or the perception of it. In contrast, individuals with problem-focused coping styles tend to actually make changes on their situation or their perception of a situation in order to make it less or no longer stressful.

2.3 Usability

Usability had become an issue in information retrieval and World Wide Web. Usability has been defined as a “quality of an optimum design, which is reflected in the effective and satisfying use of the prototype to the intended users”. Most of the reviewer evaluation on the information retrieval tools will have their own checklist (Harry & Oppenheim, 1993; Desmarais 1989; Herther, 1986b; Courtois et al, 1995). These checklists cover on the following criteria technical specification, database content, search capabilities, user interface, retrieval performance, output option, documentation and support. Checklists tend to be a tool for reviewers rather than end-users. Reviewers may talk of systems being 'user-friendly' or having poor feedback, or slow and user may be left wondering how this has been measured or whether user would agree with it. Therefore, there is a need for modification on the criteria in order to let the user become evaluator for Internet search tools (Table 2.1).

Table 2.1 Usability of Internet search tools

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Measurement</th>
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<tr>
<td>Relevance</td>
<td>Precision</td>
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<td></td>
<td>Number of relevant document</td>
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<td></td>
<td>Relative recall</td>
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<td>User Satisfaction</td>
<td>Response time</td>
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<td></td>
<td>Search interface</td>
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3. Related Studies

Many researchers have considered Internet searching to be one of the most challenging and rewarding areas of research for future information retrieval application. Searching is characterized as a process in which a user describes a request via a query and the system must locate information that matches or satisfies the request. Because not all users will search the Web in the same way, individual differences may cause difficulties in using the Web to find information. Henninger and Belkin (1996) stated that information retrieval research can be divided along the lines of its system based and user based concern. The user-based view must account for the cognitive state of the searcher and the problem-solving context.

There are few studies that have investigated cognitive style as a factor in use of hypermedia systems found performance differences between field independents and field dependents. (Repman et al, 1991; Jonassen and Wang, 1993; Liu & Reed, 1994). Nahl and Tenopir (1996) have demonstrated the importance of the affective domains as complements to the cognitive elements of online searching behavior. Ford, Wood and Walsh (1994) found significant correlations between cognitive style and online searching (LISA CD-ROM). Leader and Klein (1996) also revealed that a significant interaction between search tool and cognitive style in hypermedia database search.

Individual differences studies on Internet have been done but some of the previous studies that had been carried out are either unsystematic or unclear measurement. The measures were not always defined clearly and measures with the same names might be defined and implemented differently. Hsieh-Yee (1998) reported that some user might use the following tactics either browses or even select a few items to view when dealing with nothing relevant retrieved. Wang & Tenopir (1999) had studied the factor of cognitive, affective and physical on user interaction with World Wide Web. The participants collected in the study were more slightly field dependent. Furthermore, the bias sampling of participants affected the result in their study. They did not discuss further on the difference between field dependent and field independent on the information finding. Moss and Hale (1999) studied in detail on the cognitive styles associate linguistic factors in Internet searching. However, their experiment using one search tools only and was forced to use advanced search interface.

Problem solving is another cognitive process required for using an information retrieval system. Problem solving starts with a perceived problem. Once the problem is stated and understood, individuals then apply their knowledge to the problem and attempt to try out possible solutions.
Solutions obtained are evaluated with reference to initial problem definitions. How the problem solving process affects the Internet search is an area worthy of being studied.

Su & Chen (1999) argued that a systematic of user-oriented evaluation on search engines should be formed. Most of their findings are more on how well does the search engines perform from the user perspectives. There is no discuss on how well does the user perform search and what strategies they were using.

This study aims to examine such findings in the context of Internet searching tools. We will try to investigate the effects of search tool, cognitive and problem solving style on performance in Internet search. This paper will collect and produce qualitative and quantitative analysis to provide a better understanding of the Internet searching. The study will also utilize a factorial aptitude treatment interaction (ATI) design, (Leader & Klein, 1996) with cognitive style as the aptitude variable and search tool type as the treatment. The cognitive style variable had two factors: field dependent (FD) and field independent (FI). Search tool type had three levels: individual search engine (ISE), meta search engine (MSE), and portal (P). Leader & Klein (1996) expected that the treatment search tools would interact with the cognitive styles of the users. Besides that, we will look into usability of each search tool from the user perspective.

4. Framework for Developing Comprehensive Model of Evaluation

This section describes the method we will perform to evaluate three types of Internet search tools. We suggest a framework that covered procedure to be undertaken, evaluation to be performed, processing test results and presentation of test results. The aim of the user-oriented evaluation model was to create an appropriate framework to collect comparative data across the sample of user interfaces. The evaluation focused primarily on HCI practice and the concept of usability. A framework for developing a comprehensive model of user-oriented evaluation will base on the following tasks.

4.1 Participants

The participant will be collected in the School of Computer Science. Participants will require having a need to search for information and to bring their own search topics. They had to have some experience in using online information retrieval systems (CD-Roms, Opac) or Internet experiences (Search engine). A reward of RM20 will give to each participant upon completion of all required tasks.

4.2 Design of Study
The study followed two of 3x2 quasi-experimental design. The factors of the design are Internet search tools (ISE, MSE and P) and participant cognitive style (FI and FD). The other factors of the design are Internet search tools (ISE, MSE and P) and participant problem solving style (PF and EF).

### 4.3 Independent Variables
There are three independent variables in this study that were the levels of Internet search tools, types of cognitive style and types of problem solving style. The levels of Internet search tools were considered to be the treatment variable and was classified into three levels, namely Individual search engine (ISE), meta search engine (MSE) and portal (P). The cognitive variables included two different types that were field dependence (FD) and field independence (FI). The problem solving variables included two different types that were problem focussed (PF) and emotion focussed (EF).

### 4.4 Dependent Variables
There are nine dependent variables in this study. The following are the list of dependent variables:
1. Number of search success based on cognitive style differences and problem solving differences.
2. Measures of strategy consisted of a count of the times the following commands and facilities were used by each participant during each search: Simple keyword, Boolean operator, Phrase keyword, Natural language term and Truncation.
3. A count was kept of the number of times each participant examined a set of retrieved items.
4. Strategies used when output result being shown.
5. Length of time spent on each task: Time that the subject spent on each task was measured and averaged for each search task.
6. Length of time for the completion of information search task: Time spent for completing the search task was measured.
7. The effectiveness of each search was measured using the: precision, relative recall (number of relevant references retrieved divided by the total number of relevant references retrieved by all participants searching that task), number of relevant references retrieved and link validity. Relevance consisted of a judgement made by each participant based on viewing the original documents retrieved.
8. User satisfaction on each Internet search tools: response time, search interface, online documentation, output format, and overall search success.

### 4.5 Materials
Materials in this study included the Internet search tools, Group Embedded Figure Test, Problem Solving Inventory, self-administered questionnaire, post test questionnaire and search tasks.

### 4.6 Procedure of experiment
The problem solving inventory test was administered to a sample of 100 participants. The test was scored to identify participants who were typically "emotion focussed (EF)" (PC>22.5) or "problem focussed (PF)" (AA>51.6) problem solver. Only those identified, as typical EF or PF problem solvers will be contacted individually and ask to participate in the study. Those who agreed to participate will be asked to take the GEFT and self-administered questionnaire. Then participants will be distributed randomly into three groups.

The evaluation will be held at the small laboratory in the School of Computer Science at the University Science Malaysia. Participant will using Pentium 3 compatible PCs to conduct their searches either on Internet Explorer or Netscape and three search engine: Google, Alta Vista and Froggo.

Each test consisted of two sessions. In session 1, a ten-minute introduction will be given to the participants prior to their searches. Each participant conducted three set of search on three different search tools. For each pair of the searches, participants randomly assigned to one of the search tools in a random order and are free to use as many queries as needed on each engine. The participants were asked to think aloud while they are solving the tasks. All participants were required to finish search tasks in two hours and submit a print out of the first 10 hits from the best retrieval set of each engine.

In session 2, each participant make their relevance judgements of retrieved items based on a set of guidelines containing a definition of relevance based on a 3-point scale (R-relevant, PR-partially relevant, and N-non-relevant). Then experimenter will conduct an interview with each participant to obtain his/her ratings and reasons for satisfaction and utility. Session 2 will take about an hour.

4.7 Data collection
Data can be collected using questionnaires, online monitoring, and interview with end-users after completion of searches on search tools. All session will be recorded using audio and video. Analysis of verbal protocol will be used to provide qualitative data.

5.0 Summary and Conclusion
The above section proposes a set of procedures for comprehensive measures on evaluating Internet search. Statistical analysis of quantitative and content of analysis of verbal data will help to establish a body of sound knowledge about the user-oriented evaluation.

By understanding the effects of different individual cognitive and problem solving style on Internet search, we can provide a better understanding the individual strategies used for different types of search interface and improved the development of Internet search tool systems. In particular, we hope
to get a better understanding of which presentation structures and user interface attributes work best and why.

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