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# A Behavioral Perspective on Transmuting Successive Multi-session Web Searches

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## ABSTRACT

Multi-session successive information searches are common and could have great implications for effective Web site design. This paper intends to enhance the understanding of successive information searches by observing how the behavioral characteristics of the searchers evolve over sessions. It focuses on a specific type of successive searches called transmuting successive searches, where the searchers learn about and gradually refine their information problems along the course of information searches. The results show that the searchers' behavioral characteristics indeed exhibit different patterns in different sessions. The results also help validate a theoretical model in explaining successive searches and help revise system requirements for supporting the concerned search behavior.

## Keywords

MISE, PERSIST, successive information searches, behavioral research, multi-session searches

## RESEARCH OBJECTIVES AND QUESTIONS

Studies have shown that information searches are likely to take place over multiple sessions for the same or similar information problems (Huang, 1992; Robertson and Hancock-Beaulieu, 1992; Spink and Greisdorf, 1997; Spink, Greisdorf, and Bateman, 1998; Spink, et. al, 2002; Bateman, 1998; Spink, 1996; Spink, Bateman, and Jensen, 1999; Choo, Detlor and Turnbull, 1998). Lin and Belkin (2000, 2005) identified eight different scenarios in which a searcher could engage in more than one search sessions.

For example, in the context of electronic commerce, consumers usually have to engage in different degrees of information searches before committing to purchase transactions; they could search for the information about the electronic stores that offer the desired products in some sessions and then compare products from different electronic stores in the others. Understanding successive searches could lead to infer that information systems should possess memory to remember what users have done and thus develop the intelligence to support effective (e.g., finding useful information) and efficient (e.g., requiring less time and effort) searches. This is in line with the studies that emphasize the importance of user modeling and Web personalization (e.g., Chandler and Hyatt, 2003).

Conceptual and theoretical framework (e.g., Lin and Belkin, 2000, 2005; Spink, et. al., 2002, Vakkari, 2001; Komlodi and Soergel, 2002; Kuhlthau, 1991, 1993) help enhance the understanding of such behavior by characterizing *what* behavioral variables should be observed in successive searches and by exploring *how* behavioral variables are observed in successive searches over multiple sessions (e.g., Lin, 2005; Spink, et. al. 2002; Vakkari, 2000a).

There are several considerable limitations on these studies, however. First, the common research site of these studies except Lin (2005) is information search services available in libraries (e.g., Dialogue, Lexis/ Nexis, etc.), which at the time only supported keyword querying and rarely incorporated hypertext browsing. As a result, many studies on behavioral variables have been limited to articulation of the information needs, while overlooking the activities in browsing, organizing information collection, or monitoring the search outcomes.

Secondly, task types could affect search behavior (Lin, 2005; Vakkari, 2001; Kim and Allen, 2002). Many of these studies on behavioral variables have not considered task types as possible moderating factors. There could be some behavioral variables that are important to more specific search task types more than others.

To address these issues, this study first narrowed down the research scope and chose to focus on the transmuting successive searches, one of the eight task types of successive searches, identified by Lin and Belkin (2000, 2005). Transmuting successive searches depict the situation where the searchers learn about and gradually refine their information problems along with the course of information searches. Second, the study used the Web as the information system, where the searchers would perform full iterations of information searches (i.e., articulation, evaluation, and monitoring (Marchionini, 1995; Lin, 2005). Finally, behavioral variables exhibiting these search processes, rather than merely articulating information problems like query terms, will be studied. In summary, the following research question will be empirically explored: “How do the behavioral variables of transmuting successive searches on the Web evolve over multiple sessions?”

## LITERATURE REVIEW

The Kuhlthau’s Information Search Process (ISP) model (1991, 1993) and the other extended variations of ISP, such as Vakkari (2001), Spink, et. al. (1998, 2002), and Komlodi (2001, 2002) have studied how students search for information to write a term paper. These studies confirmed that the searchers engage in six stages of information searches through time: task initiation, topic selection, pre-focus exploration, focus formulation, information collection, and search closure. Generally speaking, the searchers cognitive abilities (e.g., level of subject knowledge and ability of articulating information problems and evaluating search outcome) will be improved when s/he progresses from one stage to the next.

However, Lin and Belkin (2000, 2005) argued that such a stage-centered perspective only explains one type of successive searches, which is the scenario of transmuting successive searches. Lin and Belkin (2000, 2005) further proposed a problem-centered perspective, postulating that the nature of information problems would affect how different cognitive and behavioral variables evolve, depending on the type of successive searches. Moreover, different task types of successive searches can transpire or lead to other types of successive searches. For example, when an academic scholar writes a new but related paper, s/he is likely to expand his/ her prior information, a result of prior information searches. The problem-centered perspective can explain the information search life cycle of the searchers over an extended period of time better than the stage-centered approach.

It should be noted that both staged-centered and problem-centered perspectives of successive searches do not rule out the possibility that the searches could take place within one single search session. The focus of these two perspectives is rather to emphasize how the search process would evolve when the searches is extended over a period of time and how to characterize that process and assess the impacts due to the interruption of time, with a framework that take into account cognitive and behavioral variables.

The behavioral variables in successive searches that have been studied have been concerned with how the searchers interact with information systems to explicate their information problems over multiple sessions. They include number of search terms (Spink, et. al. 2002; Spink, Greisdorf, and Baterman, 1997; Vakkari, 2000a), sources of search terms such as searcher question statement, librarian suggestion, thesaurus, etc. (Spink, et. al. 2002), source of documents (Vakkari and Pennasen, 2000b), search operators such as “and”, “or”, “not” and “with”, etc. (Spink, et. al. 2002; Vakkari, 2000a), uniqueness of search terms (Spink, et. al. 2002), the contributing information types or topicality in the searched documents (Vakkari, 2000b; Kuhlthau, 1993; Lin, 2005), use of the documents found (Wang and Soergel, 1998; Wang and White, 1999), number of relevant documents and precision of information collection (Spink, et. al. 2002). All these behavioral variables exhibit how searches articulate their information needs into query terms.

But in addition to the articulation of information needs, information seeking processes consist of other sub-processes, such as evaluation of search outcomes (i.e., exercising relevance judgment of the information found) and monitoring the search outcomes (i.e., determining whether one has searched for a sufficient amount of information to solve the problem at hand) (Marchionini, 1995). In the context of Web searches, navigation of the information space (i.e., browsing to recognize what information is useful as opposed to explicitly using query terms to represent what one is searching for) is a very common information seeking process as well. It is imperative to study how behavioral variables in these information seeking sub-processes, other than articulation of information needs, evolve over multiple sessions.

## THEORETICAL FOUNDATION

### Theoretical Framework: MISE

Transmuting successive searches were first characterized using the MISE framework (Lin and Belkin, 2000; Lin, 2001), and then empirically validated (Lin and Belkin, 2005). The newly revised MISE framework identified six classes of successive search experience, including searchers, search activity, search context, information attainment, information use activities, and systems.

*Searchers* are the persons who engage in searching for information themselves to ease or resolve their information problems without the intervention of intermediaries. *Systems* are the information systems that provide search features for information they collect, present, and maintain. *Search activity* is the interaction process between searcher and system. *Search context* entails the contextual factors that result from or influence the search activity. *Information attainment* is the physical product of search activity, such as a list of references or set of information objects that would help resolve information problems. *Information use activities* are the activities in which the searcher uses information from information attainment to help resolve information problems. Furthermore, *searchers* are characterized on two dimensions: *problematic situation* and *information problem*. A *problematic situation* is the user's subjective perception and estimate of carrying out a goal with his/her existing knowledge in the objective context. An *information problem* is the result of that perception and estimate, requiring external information to explicate. Information problem is a term rooted in library and information science, conceptually similar to information needs. However, information *needs* imply a static state, while information problems concedes the dynamics and evolvement of the motives for searching for information (Saracevic, 1996). *Search activity* also has two dimensions of variables: *information seeking process* and *episodes*. The explication of the information problem is manifested in the *information seeking process*, which is constituted by interacting with external information resources to search for information. The activity in between the initiation and termination of interacting with a particular external information resource is the *episode*, concerning reasons why users re-initiate and terminate a search session.

During the *search activity*, the *searchers* exhibit cognitive and behavioral differences, which are affected by the variables of the other classes (e.g., *searchers'* problematic situation and information problems, the state of the *information attainment*, etc.). The cognitive activity of the searchers consists of the four sub-processes of information seeking (i.e., articulation, evaluation, navigation and monitoring) identified by MISE, while the behavioral variables are the manifestation of those sub-processes (e.g., number of query terms, number of documents viewed or visited).

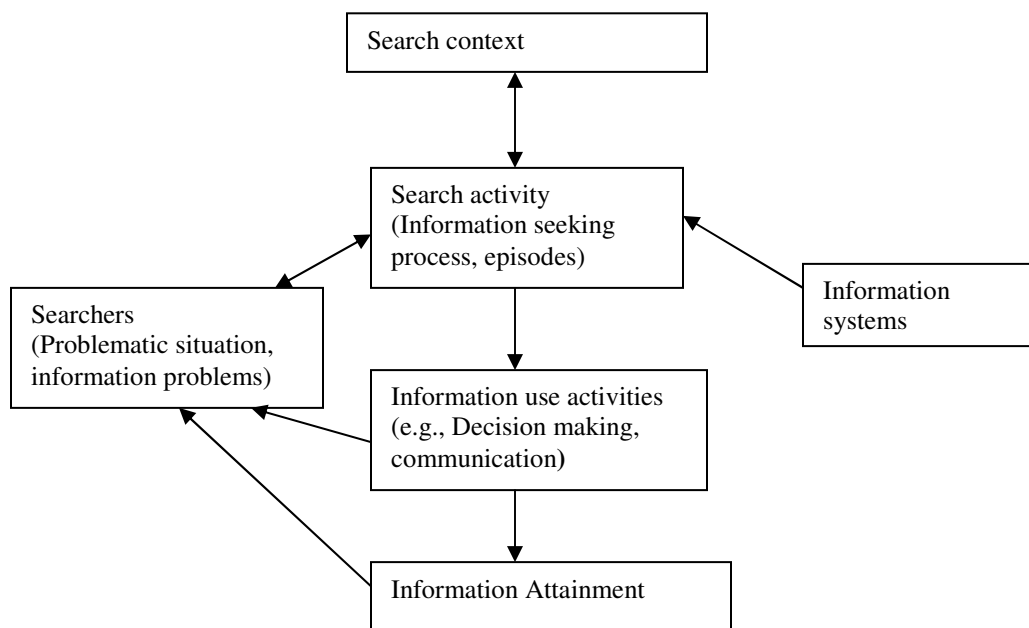


Figure 1: The MISE model

Each of these six classes, including the dimensions they entail, has a set of factors that characterize them. The factors can be either properties that describe the class or the operations that the searcher would undertake with respect to those particular classes. For a detailed list of factors in the MISE model, please refer to Lin and Belkin (2005). Figure 1 depicts the relationship among these six classes.

While the MISE model identified eight different scenarios of successive searches that could span across multiple sessions, it could not possibly arbitrarily specify the number of sessions in each scenario because how each scenario is materialized could vary depending on the actual outcome of each session. Nevertheless, by depicting how each scenario of multi-session searches could have evolved, the MISE model could help build the use cases of the search process in each scenario. The case of transmuting searches actually can be perceived as in line with what the stage-centered perspective of successive searches has portrayed: a process in which *the searchers* continuously explore the information space to learn to refine their information problems.

In short, the factors in the MISE model depict transmuting successive searches as the following. With continuous cognitive involvement with *information attainment* despite the constraints from the *information systems* and *search contexts*, the searchers' clarity about the *problematic situation*, level of *subject knowledge*, definition of *information problems* will improve over the process, which in turn would be manifested in cognitive abilities in the *information seeking process*, namely, the better ability and higher confidence to articulate information problems, navigate the information space, evaluate search outcomes, and monitor different levels of search goals.

### The theory-based system under study: PERSIST

To derive systems requirements for supporting transmuting successive searches, Lin (2002) suggested that the navigation, evaluation and monitoring activities should require more supports than the articulation activity, because with a lower level of subject knowledge and indefinite information problems, the searchers would be opportunistically looking for information cues to help clarify their problematic situation instead of proactively articulating their information problems with query terms. Lin (2002) additionally suggested the following directions to support successive searches. First, revisiting the information space of the previous sessions is crucial to improve the navigation ability because the searchers are likely to revisit information objects for re-examination of relevance, comparison with other information objects, or extraction of relevant information for explicating the transmuting information problems.

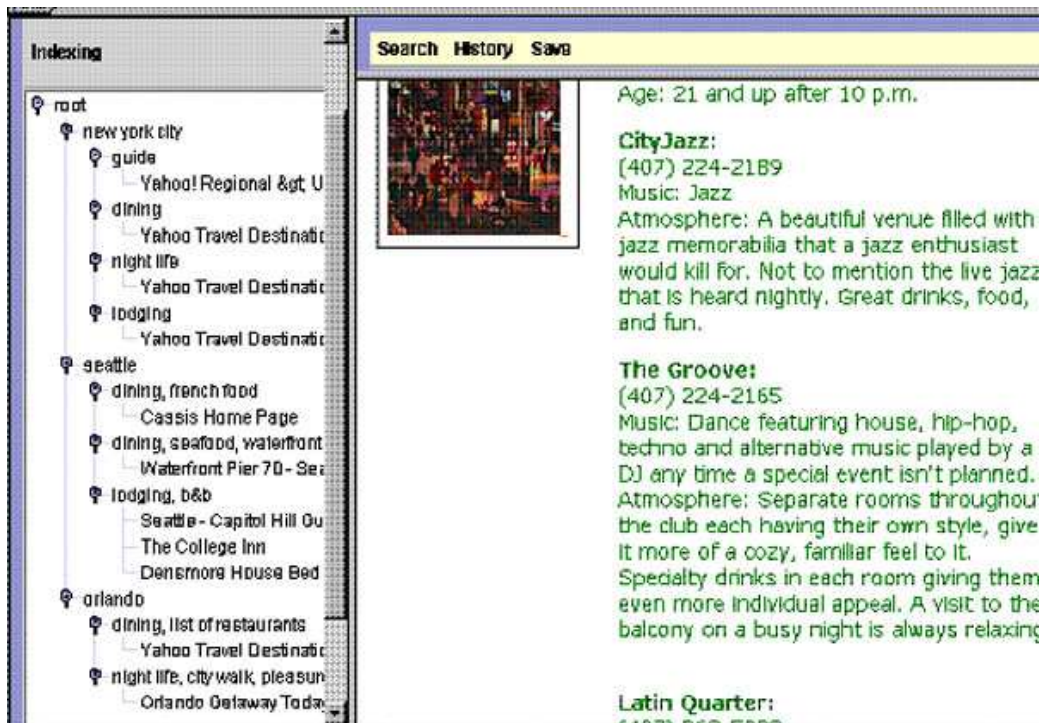


Figure 2. Snap shot of PERSIST

Secondly, keeping tracking of relevance criteria is important to improve the evaluation of search outcomes because the relevance criteria are dynamically evolving as one's information need is struggling to take in shape.

Thirdly, estimating the sufficiency of information collection in coping with one's information problems is a key to improve the monitoring activity. Thus, the information system supporting flexible organization of information objects to mitigate the current information problems could enable the searchers to quickly overview the strength and weakness of their information collection.

Lin (2002) accordingly prototyped PERsonalized and Successive Information Seeking Tools (PERSIST). To assist revisiting information objects, PERSIST enables the searchers to use words to represent information objects that could be useful to help cope with information problems and therefore it is easy to remember how to return, while IR supports the searchers when they did not index information object by browsing or specifying terms to search again search history. To assist evaluating information objects with changing criteria, PERSIST allows the searchers to compare their information attainment dynamically based on the evolved criteria at hand. To assist monitoring the sufficiency of information attainment, PERSIST allows the searchers to help identify the weakness of information attainment and thus develop information problems. PERSIST can be argued as an enhanced version of Favorites in Internet Explorer or Bookmarks in Netscape in the sense that it provides the users the ability to dynamically group and regroup all the indexed pages in one command. Figure 2 shows a snap shot of PERSIST.

### The behavioral variables studied

The requirements of PERSIST are derived from the MISE framework, as PERSIST addresses the search problems by characterizing successive information searches systematically with the variables in MISE (Lin, 2002). Thus, to study successive searches in the Web environment with PERSIST and answer the research question, the behavioral variables have to be derived from MISE and PERSIST as well.

The following behavioral variables associated with the information seeking process could be important for their *possibility* of measuring the search outcome: numbers of Web pages visited, number of Web paged indexed, ratio of revisited pages and ratio of indexed pages. The possibility is the keyword here because traditional evaluation matrix for information retrieval systems, such as precision and recall, are not appropriate for the transmuting successive searches because the searchers in such a mode of successive searches do not have definite information problems; the relevancy of Web pages to one's information problems is fluid and changed as the information problem continues to be refined. On the other hand, there is no well-established behavioral search outcome matrix for transmuting successive searches. This study is making postulations about the four behavioral variables mentioned above for the following reasons.

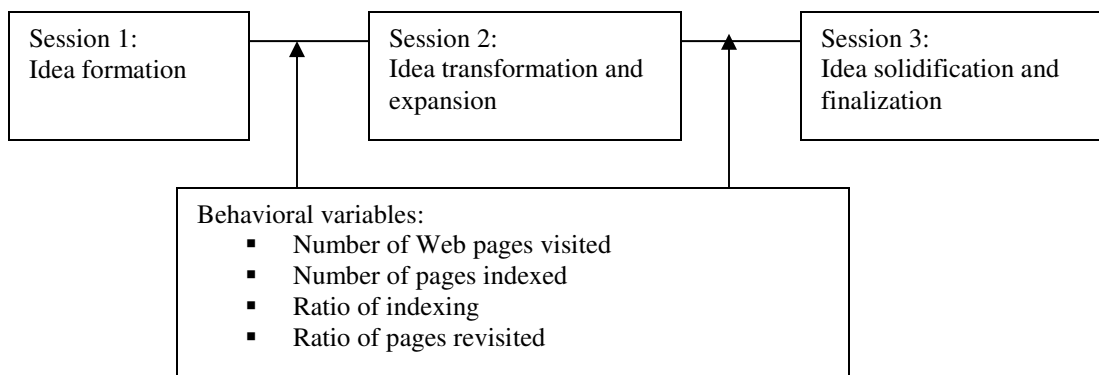


Figure 3. Research model

First, number of visited pages and number of indexed pages could indicate the searchers' productivity or effectiveness of finding useful Web pages. Second, indexing ratio, defined as the number of pages indexed over the number of pages visited, might indicate the efficiency of searches, because an indexed page connotes a relevant page. Third, defined as the number of pages visited at least twice over the total number of pages visited, revisiting ratio could validate one of the MISE postulations that revisiting is a significant activity of navigation particularly for

transmuting successive searches. As noted before, the process of transmuting information searches can be carried out in different number of sessions based on the actual outcomes of each session. To study how behavioral variables evolve through different sessions in an experiment setting, the number of episodes has to be controlled. This particular study dictated three sessions, with each embodying a different search goal. The goal in each session respectively is to formulate ideas, reformulate and expand ideas, and solidify and finalize ideas. Figure 3 summarizes the research model for the research question with the key variables.

### **Research hypotheses**

The following hypotheses are made in the form of null hypotheses.

#### **Hypothesis 1: There is some difference in the number of pages visited across different search sessions.**

Number of pages visited in each search session might not vary in the process because the increasing level of subject knowledge might be cancelled out by the increasing restriction of relevant criteria.

#### **Hypothesis 2: There is no difference in the number of pages indexed across different search sessions.**

#### **Hypothesis 3: There is no difference in the revisiting ratio across different search sessions.**

Number of pages indexed could decrease over sessions because the earlier episodes are directed by indefinitely information problems and looser relevance criteria; the searchers are likely to index Web pages freely early on and postpone the decision about how to interact with them until later sessions when their information problems are more refined or revisit them to assimilate the information and increase subject knowledge. Indexed pages encourage revisiting. Thus, revisiting ratio could increase by contrast over sessions.

#### **Hypothesis 4: There is no difference in the indexing ratio across different search sessions.**

Indexing ratio could vary over sessions as well because it is a function of number of pages indexed and visited. Since the number of pages is expected to decrease toward the completion of the overall search, the number of pages visited will not be expected to change. It can be hypothesized that the indexing ratio will decrease over sessions as well.

## **RESEARCH METHODOLOGY**

A lab-controlled experiment in which 20 recruited subjects with an even number of male and female used PERSIST was carried out. All subjects were recruited from an undergraduate class. The search system, description of subjects, procedures, conceptualization and operationalization of variables, and data collection have been described in detail by Lin and Belkin (2005).

### **Experiment task**

A concrete task of the transmuting successive searches task was presented to the subjects. Subjects were asked to search for information to plan a vacation and required to engage in three experimental sessions within one to three days in between. Subjects could stop any time after 20 minutes, but not more than 30 minutes. The first search session was controlled in a way to formulate ideas for multiple different prospective vacation destinations. The second search session was controlled so that the subjects would reformulate and expand their ideas of the vacation with newly found information. The third search session was controlled to ensure that the subjects would wrap up the search process by solidifying and finalizing their ideas on a specific vacation plan.

### **Data collection**

A proxy server was configured to maintain an online log for recording the data for the behavioral variables.

### **Data Analysis**

Paired t-tests were conducted to test the hypotheses, examining whether these behavioral variables in different search sessions yield any statistical significance.

## **RESULTS**

### **Hypothesis 1: There is some difference in the number of pages visited across different search sessions.**

The 20 subjects visited a total of 2581 Web pages in three search sessions, 1559 of which were unique. Table 1 shows the descriptive statistics for the number of pages visited. The Paired T-Test result indicates that there is no significant difference in number of total pages visited between any two sessions; however, significant differences

are found in number of unique pages visited between session 1 and 3,  $t(19) = 2.091$ ,  $p \leq .05$ , and between session 2 and 3,  $t(19) = 2.76$ ,  $p < .05$ . The hypothesis was partially supported. It appears that subjects attempted to find more unique pages in the first two sessions and less so in the last session.

|                | Session 1 | Session 2 | Session 3 | First 2 sessions | All combined |
|----------------|-----------|-----------|-----------|------------------|--------------|
| <b>Total:</b>  |           |           |           |                  |              |
| Mean           | 41.75     | 45.80     | 39.35     | 87.55            | 127.25       |
| Std. Dev.      | 14.91     | 16.11     | 17.71     | 24.55            | 29.09        |
| Minimum        | 21        | 21        | 13        | 55               | 79           |
| Maximum        | 72        | 74        | 82        | 137              | 179          |
| <b>Unique:</b> |           |           |           |                  |              |
| Mean           | 32.85     | 35.10     | 29.95     | 64.20            | 87.65        |
| Std. Dev.      | 10.67     | 10.35     | 13.09     | 16.19            | 20.95        |
| Minimum        | 18        | 20        | 9         | 42               | 56           |
| Maximum        | 57        | 53        | 65        | 91               | 128          |

Table 1 Number of pages visited by subjects

**Hypothesis 2: There is no difference in the number of pages indexed across different search sessions.**

Table 2 shows the descriptive statistics for the number of indexed pages. The Paired T-Test result shows that there is a significant difference in number of pages indexed between any two sessions. Between session 1 and 2,  $t(19) = 2.919$ ,  $p < .01$ . Between session 2 and 3,  $t(19) = 4.306$ ,  $p < .001$ . Between session 1 and 3,  $t(19) = 5.014$ ,  $p < .001$ . This suggests that subjects indexed fewer and fewer pages over sessions when they got closer to finishing the search task.

|           | Session 1 | Session 2 | Session 3 | All combined |
|-----------|-----------|-----------|-----------|--------------|
| Mean      | 6.20      | 3.05      | 0.85      | 10.05        |
| Std. Dev. | 4.73      | 3.24      | 1.57      | 7.33         |
| Minimum   | 0.00      | 0.00      | 0.00      | 0.00         |
| Maximum   | 20.00     | 14.00     | 5.00      | 28.00        |

Table 2 Number of pages indexed

**Hypothesis 3: There is no difference in the revisiting ratio across different search sessions.**

Five different revisiting ratios are relevant to this hypothesis: revisiting ratio of session 1, session 2, session 3, combination of the first two sessions, and combination of all three sessions. The first three are revisiting ratios of a single session alone, whereas the last two are revisiting ratios of accumulative sessions. The means of these five revisiting ratios are, respectively, .8052 (SD = .1113), .7885 (SD = .1045), .7696 (SD = .0963), .7430 (SD = .0845), and .6902 (SD = .0646).

The Paired T-Test result indicates that there is no significant difference in revisiting ratio between any two sessions alone. However, significant differences are found in all revisiting ratios of accumulative sessions. Between session 1 and 2,  $t(19) = 3.943$ ,  $p = .001$ . Between session 2 and 3,  $t(19) = 4.464$ ,  $p < .001$ . Between session 1 and 3,  $t(19) = 5.553$ ,  $p < .001$ . The results together suggest that although frequencies of revisiting Web pages first seen in the same sessions do not have any significant difference between sessions, the subjects revisited pages more frequently, including those first seen in the same and previous sessions, in later sessions than in earlier sessions. It implies that revisiting the pages that were seen first in the previous sessions become a more and more important activity in later sessions.

**Hypothesis 4: There is no difference in the indexing ratio across different search sessions.**

Five different indexing ratios are relevant to this hypothesis: indexing ratio of session 1, session 2, session 3, combination of the first two sessions, and combination of all the three sessions. The first three are indexing ratios of a single session alone, whereas the last two are indexing ratios of accumulative sessions. The means of these five indexing ratios are, respectively, .2151 (SD = .1698), .1204 (SD = .1556), .0440 (SD = .0868), .1283 (SD = .1072), and .1635 (SD = .1302). Moreover, 2 subjects did not index in session 1 at all, 4 not in session 2, and 14 not in the



last session. The number of subjects who used PERSIST to index Web pages decreased over session, especially sharply in the last session.

The Paired T-Test result reflects that there is a significant difference in the indexing ratio between any two single sessions. Between session 1 and 2,  $t(19) = 2.408$ ,  $p < .05$ . Between session 2 and 3,  $t(19) = 2.822$ ,  $p < .05$ . Between session 1 and 3,  $t(19) = 5.183$ ,  $p < .001$ . In addition, significant differences are also found in all indexing ratios of accumulative sessions. Between session 1 and 2,  $t(19) = 2.537$ ,  $p < .05$ . Between session 2 and 3,  $t(19) = 4.931$ ,  $p < .001$ . Between session 1 and 3,  $t(19) = 3.913$ ,  $p < .001$ . These results together suggest that subjects index less and less pages as the searches move along the sessions.

## DISCUSSION

The result of hypothesis 1 suggests that the number of unique visited pages is a better indicator than the number of total visited pages for how the search process progresses over the three sessions.

The hypotheses 2 and 4 together show that the searcher tends to index more Web pages in the earlier sessions than the latter.

The hypothesis 3 implies that revisiting pages encountered in the previous sessions becomes a more and more important activity in later sessions.

These four hypotheses about searchers' behavioral characteristics altogether confirm many of the MISE propositions: as the searcher progresses in their transmuting multi-session successive information searches, they could exhibit different characteristics in different sessions. Particularly, in earlier sessions, the searcher is more likely to have vague and less-defined information problems; s/he is focusing on gathering more information to develop ideas. Seeing more unique pages is a sign of information gathering. As information problems are less than defined, the searcher is also more likely to be uncertain about the relevance of Web pages. S/he would use more fuzzy criteria to evaluate information objects in earlier sessions when candidate pooling and weighting were a significant sub-task, and more information objects therefore would be perceived as at least partially relevant and indexed. At the same time, s/he is likely to build upon the information attainment of previous search sessions to develop information problems and gain subject knowledge. The searcher would index Web pages for revisiting later on in order to (1) re-examine the relevance of Web pages, (2) follow the links in the collected Web pages to explore more content, (3) assimilate the information within the collected Web pages, and (4) extract the information from the collected Web pages to complete a task product (e.g., a travel itinerary plan).

The results of all these eight hypotheses have great implications for system design. The results suggest that different episodes of multi-session, successive, transmuting information searches could demand for different types of system supports. While a mechanism like PERSIST seems useful for supporting idea reformulation and expansion, more effective mechanisms are needed for the episodes of idea formation and idea solidification. Furthermore, the importance of *personalized* support for effective and efficient successive searches is manifested through the results. It is crucial for the information system to *know* the searcher (and his/ her successive search episodes) so that it could provide appropriate supports for different phases of information searches.

## CONCLUSION

The results of this study can be expected to enhance the understanding of successive searches, as it validated the descriptive and explanatory powers of MISE, a conceptual model on successive searches. It also helps validate the legitimacy of system requirements derivation from MISE to PERSIST. At the end, it helps revise the requirements of PERSIST, since it also observed how PERSIST was used to support successive searches.

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