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Factors affecting the selection of search tactics: Tasks, knowledge, process, and systems

Iris Xie *, Soohyung Joo

School of Information Studies, University of Wisconsin-Milwaukee, P.O. Box 413, Milwaukee, WI 53201, United States

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ABSTRACT

This study investigated whether and how different factors in relation to task, user-perceived knowledge, search process, and system affect users' search tactic selection. Thirty-one participants, representing the general public with their own tasks, were recruited for this study. Multiple methods were employed to collect data, including pre-questionnaire, verbal protocols, log analysis, diaries, and post-questionnaires. Statistical analysis revealed that seven factors were significantly associated with tactic selection. These factors consist of work task types, search task types, familiarity with topic, search skills, search session length, search phases, and system types. Moreover, the study also discovered, qualitatively, in what ways these factors influence the selection of search tactics. Based on the findings, the authors discuss practical implications for system design to support users' application of multiple search tactics for each factor.

1. Introduction

Search tactics represent the key and fundamental level of search activities during the information searching process. A search tactic is considered a basic unit of analysis of the information searching process. A search tactic refers to a move or moves, including search choices and actions that users apply to achieve a specific objective in the information searching process. The main difference between a search tactic and a search behavior is that a search tactic might contain a series of search behaviors and these search behaviors are part of a search tactic applied to accomplish a specific objective. Research concerning search tactics has been conducted mainly in two ways: identification of search tactics and analysis of search tactic patterns (Bates, 1979; Fidel, 1985; Shiri & Revie, 2003; Shute & Smith, 1993; Xie, 2008). Search tactic selection in the web environment shows more dynamic interactions between users and IR systems than in traditional searching environments. In web IR systems, users usually apply various types of search tactics such as searching known addresses, opening multiple tabs, moving forward and backward through hyperlinks, query formulation and reformulation, scanning search results, and saving documents (Aula, Jhaveri, & Kaki, 2005; Bhavnani, 2001; Thatcher, 2006; Wang, Hawk, & Tenopir, 2000).

Previous studies in search tactic research have focused more on tactics, themselves, or tactic patterns, but few have tried to examine the effects of various factors that can influence the application of search tactics, such as task types, user's perceived knowledge levels, search processes, and system types. According to previous research, work tasks influence search activities and search performance (Byström & Järvelin, 1995; Byström, 2002), while search tasks affect search tactics (Kim & Allen, 2002; Shiri & Revie, 2003). Users' perceived knowledge, including search experience and domain knowledge, and their interactions have an impact on their search behaviors (Aula, 2003; Hsieh-Yee, 1998; Lazonder, Biemans, & Wopereis, 2000; Palmquist & Kim, 2000; Wildemuth, 2004). Users also exhibit different behaviors, including tactics at different stages

* Corresponding author.
E-mail addresses: hiris@uwm.edu (I. Xie), sjoo@uwm.edu (S. Joo).

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and phases of the search process (Kuhlthau, 1991; Vakkari, 2001; Vakkari, Pennanen, & Serola, 2003). In addition, different types of IR systems create different search contexts that lead to the application of simple or complicated query-related and other search tactics (Jansen & Pooch, 2001; Wolfram & Xie, 2002; Xie, 2004).

Previous research has explored factors in relation to search behaviors; however, most of the research only focused on one or two factors. More importantly, few studies have investigated multiple search tactics beyond query-related tactics, and few of them applied both quantitative and qualitative methods into the data collection and analysis. This study intends to investigate the effects of different factors in relation to tasks, users' perceived knowledge, search processes, and systems on users' search tactic selection. Findings are based on the analysis of real users' searching processes in achieving their real tasks. The findings of this study could help researchers better understand how users develop their search tactics under the influence of various factors in different web-based information environments. Also, the investigation of different factors in relation to tactic selection could offer practical implications for IR system design to support users' multiple search tactic application in their search processes.

2. Literature review

In this literature review section, previous studies that identified and examined factors associated with search tactics are reviewed in relation to task types, users' perceived knowledge levels, search processes, and system types.

2.1. Task types

Task is a key factor that influences search behaviors, including search tactics (Vakkari, 2003). Different types of tasks have been identified and classified in the Web search environment (Li, 2009; Xie, 2009), and both work tasks and search tasks have an impact on search behaviors. Xie (2009) identified dimensions of work task (nature, stages, and time frame) and search task (origination, types, and flexibility), and found that information-seeking processes, such as planning, search strategy selection, and shifts in goals, varied in different work and search tasks. Byström and Järvelin (1995) identified five different complexity-level tasks from automatic information processing to genuine decision and discovered that the types of information sought varied in different task complexity levels. Byström (2002) further examined the relationships between perceived task complexity and information-seeking activities, focusing on a need for and consequent use of information sources. Her findings reported that task complexity has a direct relationship with source uses; for example, internal official documents are most used in automatic information processing tasks, while human sources are the most used in decision tasks. In her experimental study with 24 participants, Li (2010) found that work tasks dramatically affect users' interaction performance, in particular, search efficiency and effectiveness. In her results, search efficiency and effectiveness were higher in less complex decision tasks, whereas they were lower in more complex intellectual tasks.

Compared with work tasks, search tasks are found to be more associated with search tactics and moves. Hsieh-Yee (1998) identified three groups of Web user search tactics: tactics for starting, tactics for too many item retrieved, and tactics for no relevant items retrieved; she then compared the patterns of tactics in two different search tasks: known-item searches and subject searches. She found there were no significant differences of search tactics used for these two types of search tasks. Kim and Allen (2002) examined the effect of two search tasks, including known-item searching and subject searching, on participants' search activities. In their experiment, the effect of search task types on search activities, such as Web site views, and search tool uses, was confirmed as significant statistically. Shiri and Revie (2003) evaluated the effects of search topic complexity on cognitive and physical search moves within the interface of a thesaurus-enhanced information retrieval environment. Their findings indicated that an increased number of cognitive and physical search moves were associated with more complex topics. In her experimental study, Hung (2005) empirically examined how users' selections of search tactics differ by search task type, specific search, general search, and subjective search. Users employed more complex search tactics in general or subjective search tasks than in specific search tasks. Liu, Gwizdka, Liu, Xu, and Belkin (2010) investigated how task type and task situation influence users' query reformulation behavior, based on an experimental study with 48 participants. Their results showed that three types of task structures, including simple, hierarchical, and parallel searches, are associated with participants' query reformulations. While specialization reformulation strategies were most frequently applied in simple and hierarchical searches, generalization strategies were most applied in hierarchical searches. Search tasks not only affect adults' but also children's search tactics application. According to Bilal and Kirby (2002), children used more natural language queries and looped and backtracked more searches on fact-based tasks, and browsed more on self-generated tasks. They also applied more analytic searches on these two tasks than on research tasks.

2.2. Users' perceived knowledge level

Users' perceived knowledge levels have long been investigated for their relationships to information search behaviors, including tactics and strategies. Researchers examined the effects of different types of users' perceived knowledge, in particular, search experience and domain knowledge.

Level of search experience has been demonstrated to lead to different search behaviors, for example, users' preference for specific features of the system (Hill & Hannafin, 1997) and the increased likelihood that inexperienced users will use

hyperlinks (Palmquist & Kim, 2000). Information retrieval knowledge is also related to search behaviors. For example, the most experienced groups perform the most cost-effective searches (Howard, 1982), and there are differences between novice and expert users in relation to the number of pages, task solution time, and types of items accessed (Saito & Miwa, 2001). In addition, based on examining 25 students' search processes, Lazonder et al. (2000) found that expert users are usually better at searching, but not at browsing, than novice users.

Simultaneously, prior studies have shown that domain knowledge has an impact on search tactics. Hsieh-Yee (1993) investigated domain knowledge's impact on search tactics for both novice and experienced users, and she found that domain knowledge affected search tactic selection of experienced users. Wildemuth (2004) concluded that the effects of domain knowledge on search tactic formulation changed over time as participants' domain knowledge changed. Hembrooke, Granka, Gay, and Liddy (2005) examined the effects of domain knowledge on query-related tactics such as query creation and modification tactics, and their results revealed that expert users apply more elaboration and more complex queries whereas novices engage in less effective search strategies, such as plural making/taking, redundancy, poke and hope, and backtracking.

Shiri and Revie (2003) investigated how topic familiarity and prior topic search experience influence users' cognitive and physical moves in IR systems. Their findings indicated that users searching moderately familiar and very familiar topics used more moves than users searching for unfamiliar topics; however, prior topic search experience was found not to affect the number of cognitive or physical moves.

Interestingly, not all studies reach an agreement on the influence of domain knowledge. According to Aula (2003), domain expertise did not have an effect on the query formulation, but the level of experience in using Web was related to query formulation behaviors. Hsieh-Yee (1993) found that search experience affects searchers' search tactics, but, at the same time, she pointed out that domain knowledge could be a factor after searchers have gained a certain amount of search experience.

2.3. Search process/system types

In addition to tasks and users' knowledge levels, search process is another important factor that is associated with search tactics. Users exhibit search behaviors or tactics at different stages or phases of the search process. In this paper, the difference between phases and stages lies with the fact that phases are associated with a single search session, while stages are associated with multiple search sessions, although researchers have used different terms to represent these two concepts. In her information search process (ISP) theory, Kuhlthau (1991) identified six stages and showed the changes in users' physical actions, cognitive thoughts, and affective feelings in each stage. The ISP theory presents how users search behaviors change as the search stage changes. Vakkari and his associates (Vakkari, 2001; Vakkari et al., 2003) integrated Kuhlthau's six stages into a three-stage model, including pre-focus, formulation, and post-focus, and found that users changed their search tactics corresponding to their changes of stages. In particular, as users moved forward through stages, they increased their use of search formulation tactics (e.g., intersect, vary, and parallel) and application of conceptual search tactics, and decreased the employment of operational tactics. These results are validated and specified in another study of users' changing of search tactics in an academic setting, in which Xie (2009) found that stages of tasks play a crucial role in influencing users' application of information-seeking strategies. While users focused on exploring different topics at the pre-focus stage, at the formation stage, they concentrated more on how to formulate the query to represent their topics. During the post-focus stage, they applied the pearl-growing strategies, checked with human resources about their search results from the formation stage, as well as searched for different formats of documents.

Researchers investigate phases of the search process as well as the different search stages. Robins (2000) focused on the processes of shifts of search foci in mediated IR interaction via discourse analysis. Six foci were highlighted in terms of documents, evaluation of search results, search strategies, IR system, topic of the search, and information about the user; however, his research did not find patterns among the transition in foci. On the contrary, Olah (2005) pointed out that there were specific search patterns identified, especially iterative loops and linear moves corresponding to the 14 states of the process: database selection, review result set, and the physical delivery of result set. Kules and Shneiderman (2008) uncovered that users are likely to explore as they are more organized in a search process. Additionally, Liu and Belkin (2010) identified task stage as one of the factors related to search behaviors when performing three assigned search tasks in different stages.

Users' search tactics and strategies vary in different types of systems. Different types of Web systems, such as OPAC, online databases, and web search engines, have different interfaces and document collections. Wolfram and Xie (2002) characterized two IR contexts in terms of content, usage behaviors, and accessibility. While the traditional IR context is related to online databases, a popular IR context is associated with Web search engines. These two contexts present different search behaviors by their users. Jansen and Pooch (2001) compared users' different search behaviors, such as number of queries, search length, and use of advanced features, in traditional IR, OPAC, and Web contexts, focusing on query searches based on literature reviews. Web users exhibit different search behaviors compared to users searching traditional IR systems such as online databases. For example, web search engine users are likely to create shorter queries, modify fewer queries, and examine only top ranked pages compared to traditional information system users (Silverstein, Henzinger, Marais, & Moricz, 1999; Spink, Wolfram, Jansen, & Saracevic, 2001). After comparing users' use and evaluation of online databases and Web search engines, Xie (2004) found that online databases enable users to construct and modify their complicated queries and other search features while Web search engines lead users to come up with simple queries.

Prior studies identified different factors and investigated the effect of those factors on users' search behaviors. These studies have greatly contributed to the understanding of how users select search tactics in their search processes. In spite of these

contributions, however, the existing research has some limitations. First, little research has examined different factors related to search tactics in multiple dimensions. Most prior works have concerned a specific aspect among task type, user knowledge, search process, and system types. Second, few studies have covered multiple search tactics in examining the related factors. Most studies focused only on query-related search tactics, even though exploration and evaluation tactics are also critical. Third, limited numbers of studies applied both quantitative methods, including inferential statistics and qualitative methods, in their studies. Fourth, many previous studies relied on experimental designs with assigned tasks, as opposed to real users with real tasks. Fifth, there is little research that investigates the association between system types and search tactic selections. The limitations of previous research calls for the need to investigate the factors associated with tactic selection from tasks, users' perceived knowledge, search process, and system types by applying both quantitative and qualitative methods.

3. Research questions and associated hypotheses

This study intends to investigate the factors in relation to search tactic selection, and address the following research questions and associated research hypotheses:

R(Q1) Is there a relationship between types of tasks and search tactic selection? If yes, how?
- H1-(1) There is a significant relationship between work task type and search tactic selection.
- H1-(2) There is a significant relationship between search task type and search tactic selection.

R(Q2) Is there a relationship between user characteristics and search tactic selection? If yes, how?
- H2-(1) There is a significant relationship between users' familiarity with search topics and search tactic selection.
- H2-(2) There is a significant relationship between users' familiarity with resources and search tactic selection.
- H2-(3) There is a significant relationship between users' search skills and search tactic selection.

R(Q3) Is there a relationship between search process and search tactic selection? If yes, how?
- H3-(1) There is a significant relationship between search session length and search tactic selection.
- H3-(2) There is a significant relationship between search phase and search tactic selection.

R(Q4) Is there a relationship between system types and search tactic selection? If yes, how?
- H4-(1) There is a significant relationship between system types and search tactic selection.

4. Methodology

4.1. Sampling

To test the proposed hypotheses, the authors recruited 31 participants from the Greater Milwaukee area responding to fliers or newspaper advertisements. They represent general users with different sex, race, ethnic backgrounds, education and literacy levels, computer skills, occupations, and other demographic characteristics. We selected only the characteristics that affect the selection of search tactics identified by previous literature and the authors' own works to test the associations. The fliers and newspaper advertisement looked for users of the World Wide Web for business, pleasure, or other reasons. Potential participants were 18 years or older who live in the Milwaukee area and had some online searching experience. In addition, the incentive and the instructions in relation to how to participate in the study were also mentioned. Participants were each paid $75 for their involvement in the study. Table 1 presents participant characteristics.

Table 1
Characteristics of participants ($N = 31$).

Demographic characteristics		Number	Percentage (%)
Gender	Male	10	32.3
	Female	21	67.7
Age	18–20	1	3.2
	21–30	13	41.9
	31–40	5	16.1
	41–50	7	22.6
	51–60	5	16.1
	61+	0	0.0
Native language	English	29	93.5
	Non-English	2	6.5
Ethnicity	Caucasian	29	93.5
	Non-Caucasian	2	6.5
Computer experience	Expert	3	9.7
	Advanced	21	67.7
	Intermediate	7	22.6

4.2. Data collection and procedures

First, participants were instructed to fill in a pre-questionnaire requesting their demographic information and their experience in searching for information. From the pre-questionnaire, data in relation to search task type, work task type, familiarity with topic, and familiarity with source were collected. Second, participants were asked to keep an "information interaction diary" for 2 weeks to record the process of achieving one work-related and another personal-related task. The diaries require participants to log their source selections, search tactics, and reasons associated with why they applied or did not apply different types of search tactics. From the diaries, the authors attempted to identify factors behind their selection of search tactics qualitatively. Third, think aloud protocols and logs were employed to record their search processes and associated verbal protocols. Participants were invited to come to the lab to search for information for one work-related and one personal search tasks. They were instructed to "think aloud" during their information-seeking process. Their search processes were captured by Morae, a usability testing software that records users' movements, as well as capturing their "think aloud protocols." Finally, participants were also asked to fill in post-questionnaires. Their answers regarding their selection of information sources, their search tactics, their problems, and factors affecting their selection of search tactics were noted.

4.3. Data analysis

The study considered eight main factors and statistically tested whether there are relationships between these factors and search tactic selection. Dimensions, types, definitions, and categories under each type of factor are presented in Table 2. In

Table 2
Types of factors with definitions.

Dimensions	Types of factors	Definitions	Categories under each type of factor
Task types	Work task	Types of tasks that lead to the information searching	Scholarly task (research project; writing a paper, writing a book, etc.); Occupational task (identifying a list of US law firms that specialize or have experience working with credit union mergers and acquisitions, finding SQL injection techniques and remediation, etc.); Popular task (entertainment, travel, shopping and so on)
	Search task	Types of search results a user intends to obtain	Specific information searching ("I'd like to look at the conditions of 2 local ski hills."); Known-item searching ("I want to know if the UW-Milwaukee library has a copy of the book 'History of Racine and Kenosha Counties from 1879'."); Subject-oriented searching ("I want to learn more about both the positive and negative effects that caffeine has on the body.")
Users' perceived knowledge	Familiarity with search topic	To what extent a user perceives his/her familiarity with the topic he/she is searching	Five-point Likert scale (1 not at all familiar – 2 a little familiar – 3 somewhat familiar – 4 somewhat more familiar – 5 extremely familiar)
	Familiarity with resource	To what extent a user perceives his/her familiarity with the resource in which he/she is searching	Five-point Likert scale (1 not at all familiar – 2 a little familiar – 3 somewhat familiar – 4 somewhat more familiar – 5 extremely familiar)
	Search skill	Levels of self perceived "knowledge and skills necessary to utilize the Web and other Internet resources successfully to solve information problems" (Hölscher & Strube, 2000, p.338)	Advanced; Expert
Search process	Search session length	Length of time that a user takes to complete a search session	Short search; Medium-short search; Medium-long search; Long search
	Search phase	Different phrases within a single search session	Beginning phase (First six search tactics within a single search session); Middle phase (Rest of search tactics in addition to the first and last six search tactics); Ending phase (Last six search tactics within a single search session)
System	System type	Types of Web-based IR systems used by participants to achieve their information tasks	Webpage (individual, organizational sites, Wiki, etc.); Search engine (Google, Yahoo, etc.); Online database (EBSCOhost, PubMed, etc.); OPAC (Milwaukee county public library catalog, etc.)

this paper, dimensions refer to different aspects that influence search tactic selection, and each dimension has its own factors.

The unit of analysis in this study is each search tactic. Search tactics were coded using a scheme developed mainly by Xie (2008), consisting of 13 types of tactics. For this study, the classification scheme was slightly modified. "Accessing" was divided into two different tactics, "accessing forward" and "accessing backward," considering that the direction of accessing has different meanings in the search process. "Evaluating" was further divided into "evaluating search results" and "evaluating an individual item," because the authors found that evaluating behaviors differed by participants under different circumstances. For instance, when participants looked at a list of search results, they were likely to assess quickly to select an item, whereas when they faced each individual document, they usually made more of an effort to judge its relevance. Thus we created "evaluating search results" and "evaluating an individual item" categories to code quick judgments and thorough assessments, respectively. For simplicity, each tactic has been represented by an acronym, and an italic font was applied to the acronym. Table 3 presents the coding scheme of types of search tactics.

To test the inter-coder reliability of each search tactic, two researchers independently coded 20 tasks from 10 participants randomly selected from 60 tasks performed by 31 participants. The inter-coder reliability for coding each search tactic was .97 according to Holsti's (1969) reliability formula. Reliability = $2M/(N1 + N2)$, where M is the number of coding decisions on which two coders agree, and $N1$ and $N2$ refer to the total number of coding decisions by the first and second coder, respectively.

A total of 3756 tactics were observed in 60 search tasks performed by 31 participants. The findings of frequency and proportions of applied types search tactics can be found in another paper. Major tactics refer to frequently applied tactics such as *AccF*, *AccB*, *EvalR*, *EvalI*, and *Use*, whereas minor tactics refer to less frequently applied tactics such as *Lead*, *Mod*, *Org*, and *Rec* (Xie & Joo, 2010a). In this paper, collected data were analyzed quantitatively and qualitatively. For the quantitative analysis, 60 search sessions were analyzed using categories identified in Table 2 above. In order to ensure the reliability of data coding, one researcher first examined each individual search session with its think-aloud protocols and identified and assigned different types of factors and categories under each type of factor, and then another researcher analyzed and checked

Table 3
Coding scheme of types of search tactics.

Code	Types of search tactics	Definition	Example
Lead	Identifying search leads to get started	Discover information as search leads at the beginning of the search process	"because my topic is very recent and it is business related, one of my first choices is cnn.com"
Creat	Creating search statement	Come up with a search statement for searching	[type in] "I am going to search pea shoots"; [using a given form] "fill fields with date and time to query what is available"
Mod	Modifying search statement	Change a previous search statement to specify or broad search results	"[previous query] London city tour → [modified query] London three-day tour"
EvalI	Evaluating individual item(s)	Assess relevance/usefulness of an item, or authority of an item	"this article has references so that might be reliable. . .this is new information so I think this is a good website"; "the first site [this site] was useful it gave a lot of information about kennel cough the symptoms and how can we treat it"; "this site was not useful at all; it did not provide much info about it."
EvalR	Evaluating search results	Quickly assess the relevance of search results	"I am still skimming my Google results and I am not finding any related results."
Rec	Keeping a record	Keep records of metadata of an item(s) before accessing it/them	[paper record] "so it is [the book] available at Central so I would write down the call number." [book marking] "I want to bookmark it."
AccF	Accessing forward	Go to a specific item or web page that has not been accessed in the search by using direct location, tracking meta-information, or hyperlinks	[type in URL] "type URL, frommers.com" [link] "clicks link to Near Southside under heading Outreach communities"
AccB	Accessing backward	Go back to a previous page by using direct location, tracking meta-information, or hyperlinks	[type in URL] "goes back to homepage through URL" [link] "clicks library back button to results"
Lrn	Learning	Gain knowledge of system features, system structure, domain knowledge, and database content	"Learn how to use Google earth"
Xplor	Exploring	Survey information/items in a specific site	"[looking at LOC subjects] . . .ION exchange method, so I could see if that has anything to do with sugar, I could go back to Google and figure that out"
Org	Organizing	Sort out a list of items with common characteristics	"sorted results by length of antenna"
Mon	Monitoring	Examine the search process or check the current status	"Let's see I found out about size, type, range, understand why the size limits, batteries, how tiny they can be, put the antenna on a circuit board."
Use	Using/obtaining	Use searched information to satisfy information needs or obtain information in physical or electronic formats	"Dynasty trust – this is kind of nice, [PDF article]. I would print this and use it for my work files."

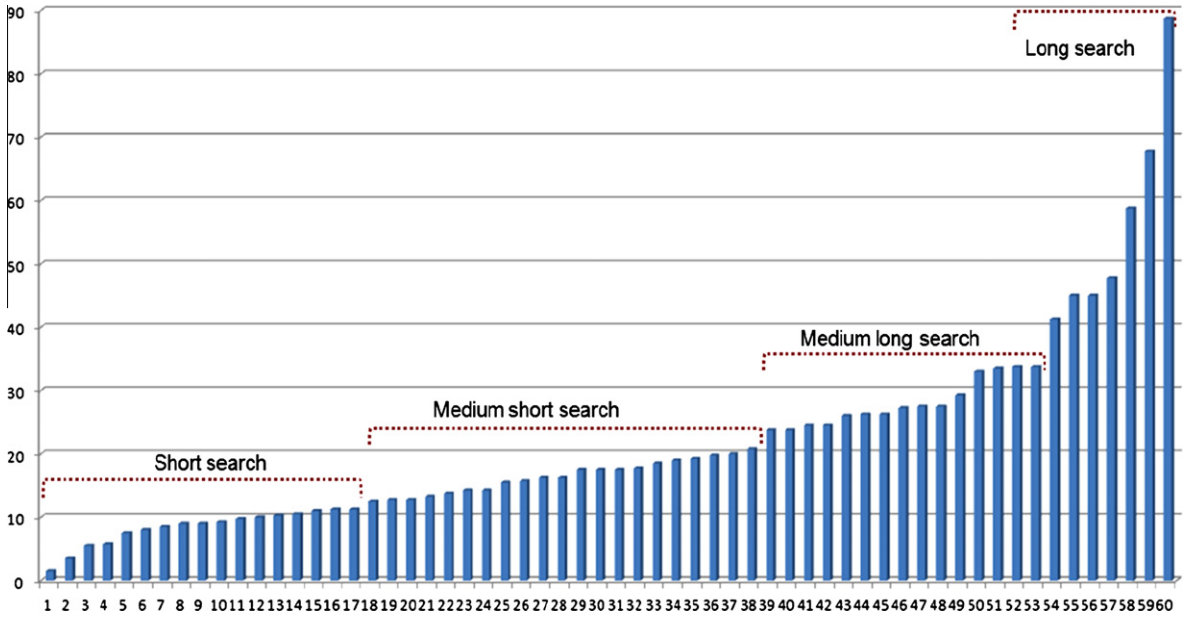

Fig. 1. Time length distribution of search sessions.

whether the assignment was appropriate. If there were disagreements, the two researchers worked together to reach an agreement. Then, the authors established eight hypotheses to examine the relationships between identified factors and search tactic selection statistically.

In order to investigate whether search session length is associated with tactic selection, the authors grouped 60 cases into four categories based on search session length. As shown in Fig. 1, four groups of search length were identified – short search, medium-short search, medium-long search, and long search – based on the three elbows observed in the distribution. Short searches took less than 11 min 15 s. Medium-short searches took between 12 min 30 s and 20 min 35 s. Medium-long search took between 23 min 45 s and 33 min 45 s. Long search cases took 35 min or more.

To have an understanding of how tactic selection differs by search phases, the authors divided a search session into beginning, middle, and ending phases. Since the average number of tactics applied in one search session in the dataset was about 60, about six tactics, which account for approximately 10% of tactics in a single session, were considered to be appropriate to identify beginning and ending phases in this study. The authors also examined the search sessions that consist of less or more than 60 tactics and found that the patterns of search tactics identified in a paper (Xie & Joo, 2010a) in beginning phases (query initiation strategy and known item exploration strategy) and ending phases (results evaluation strategy and exploration strategy) did not change over the length of the search sessions. The rest of the tactics were considered to be middle phases. Fifty-three of the sixty cases that contained at least 24 tactics were analyzed, because the middle phases should contain the same or more search tactics than the sum of beginning and ending phases.

Using the information of classified factors and search tactic frequency, the authors conducted eight cross-tabulation analyses and examined the significance of association for each analysis using Chi-square tests, since the data concerns the frequency of applied tactics. When the association turned out to be significant, the authors tried to identify unique patterns. In addition, qualitative analyses were conducted to identify the reasons behind the observed search tactic selection patterns. Using the data from think-aloud protocols and diaries, the patterns and reasons related to observed tactic selection were explained in detail.

5. Results

This section reports the results of the proposed research questions and corresponding hypotheses. While transaction logs offer data in relation to application of search tactics, system type, and length of search sessions, the pre-questionnaires provide data in relation to search task type, work task type, familiarity with topic, familiarity with resource, and search skills. In order to investigate the associations between these factors and tactic selection, the authors conducted cross-tabulation analysis with Chi-square tests. As the observed counts of two less frequently used tactics, *Lrn* and *Mon*, were too small to be included in Chi-square test, those two tactics were excluded from the statistical analysis. Since the frequency of search tactics of the dependent variable is distributed into 11 categories, the percentage of difference among categories of each independent variable for each category of dependent variable appears low in the dataset. Moreover, there are fewer frequencies of minor tactic occurrences in this dataset. Therefore, the authors focused only on the differences among different categories

that were about 3% or more for major tactics and 1% or more for minor tactics when interpreting empirical findings. Some of the small differences were discussed only if qualitative data shed some light on them. In addition, qualitative data derived from verbal protocols and diaries were used to offer patterns and reasons behind the selection of search tactics. The results are organized by dimensions of factors: task type, user perceived-knowledge level, search process, and system types.

5.1. Task type and tactic selection

5.1.1. Work task types and tactic selection

The authors identified three work task types based on the categories: scholarly task, occupational task, and popular task. The numbers of tactics applied in each task were 723, 1277, and 1735, respectively. Table 4 presents cross-tabulation of work task type and tactic selection. A Chi-square test rejected the null hypothesis, indicating the significant association between work task types and tactic selection: $\chi^2(20, N = 3735) = 96.856$, $p < .01$.

In achieving scholarly work tasks, the participants exhibited unique tactic selection patterns. Scholarly task relied more on search result evaluation tactics, *EvalR*. The percentage of *EvalR* (14.5%) was relatively higher in accomplishing this type of task than other types of work tasks. This finding implied that participants more frequently applied search result evaluation tactics for scholarly search tasks. Also, the proportions of *Org* (3.2%) *and Mod* (4.1) tactics were comparatively higher in performing scholarly tasks than in performing other types of tasks. For instance, a participant applied *Org* tactics to classify search results in a scholarly search task. She said: "I sorted the information into Positive Health Effects, Negative Health Effects, Physiological Mechanism and Other to better organize my results (*Org*)."

As to occupational tasks, the percentage of *Xplor* was relatively higher compared to scholarly tasks, accounting for 11.6%. However, the percentage of *EvalR* was relatively lower, 10.0%. In the data, the authors observed that the participants frequently browsed lists, such as a list of companies, products, and item prices, to achieve their given work tasks. For example, a participant described a browsing activity while carrying out a work-related task: "With the information (a list of firm names) ... I will be working next on browsing the companies' websites to determine which 2 or 3 may be most useful to our needs."

The results also showed the pattern of tactic selection related to popular work tasks. Participants applied relatively higher percentage of *AccF* (28.6%) in performing popular work tasks than scholarly tasks. Simultaneously, participants employed high percentage of *Xplor* tactic (10.6%). These findings indicate participants were likely to go through different items through hyperlinks to accomplish popular tasks. In addition, the percentage of the *Mod* tactic was relatively lower compared to scholarly tasks, showing only 1.9%. This means participants conducted less formal searches in achieving popular work tasks. The diary data offered some explanations for the tactic selection. For instance, a participant provided a typical reason for not applying *Org* or *Mod* in searching for popular tasks: "I did not organize my results because I wanted to just read through them freely"; "This was an informal search. I didn't have a specific process I was following."

In addition, the authors found that the participants were likely to apply more specific tactics for certain search topics of popular tasks. Particularly, in performing shopping tasks, participants were more likely to apply site comparison strategy, in which participants explore different sites with similar characteristics. Accordingly, *Xplor* tactics were applied frequently. Here is one example that shows successive exploration: "I went to BestBuy.com ...; I went to Circuitcity.com...; I went to walmart.com...; I went to target.com (successive *Xplor*'s)."

In analyzing the results, the authors found that participants selected different types of IR systems for different types of work tasks. One interpretation of the results can be that there are interactions between types of tasks and types of IR systems. Since types of work tasks led participants to select different types of IR systems, types of IR systems could determine the selection of search tactics. The authors conducted a Chi-square test to analyze the relationships between types of tasks and types of IR system selection. The Chi-square test result indicates a significant relationship between these two factors: $\chi^2 = 67.21$ ($df = 6$), $p < .01$.

Table 4
Cross-tabulation of work task type and tactic selection.

Tactic	Work task type		
	Scholarly ($N = 723$) (%)	Occupational ($N = 1277$) (%)	Popular ($N = 1735$) (%)
Lead ($N = 121$)	4.1	3.1	3.0
Creat ($N = 149$)	4.8	2.7	4.6
Mod ($N = 101$)	4.1	3.0	1.9
Evall ($N = 837$)	20.5	23.0	22.8
EvalR ($N = 412$)	14.5	10.0	10.3
Rec ($N = 41$)	2.2	.9	.8
AccF ($N = 1024$)	25.2	27.0	28.6
AccB ($N = 383$)	10.0	11.3	9.6
Xplor ($N = 385$)	7.3	11.6	10.6
Org ($N = 44$)	3.2	.3	1.0
Use ($N = 238$)	4.0	7.2	6.7

In the dataset, participants showed different patterns of resource uses by work task type. Participants used search engines for popular tasks (47.1%) more frequently than they used them for occupational (38.1%) or scholarly (44.5%) tasks. Participants used Web pages for occupational tasks (64%) more frequently than they used them for popular (51.6%) or scholarly (44.5%) tasks. Participants used OPAC and online databases for scholarly tasks (4.4% and 6.6%, respectively) more frequently than they used them for popular tasks (1.2% OPAC; 0% online database) or occupational tasks (0.4% OPAC; 0% online database).

In addition, search logs of participants also shed some light on the interactions. In performing scholarly tasks, the IR systems (e.g., online databases) they chose offered more system features to support search result evaluation and organization tactics. For example, one participant looked for literature on Silicosis or exposure to Silica in his research (scholarly) task, and selected PubMed for his searches. In this case, he mostly applied keyword search, organized, and evaluated search results iteratively (EvalR) in PubMed until getting enough useful literature for his research work. Online databases, which are usually selected in accomplishing scholarly tasks, well support more query searching and search result evaluation along with search result organization options. Participants employed Web search engines and Web pages more frequently in searching for popular tasks such as travel, shopping, and entertainment. For example, one participant who tried to look for some new running shoes started with Google, and checked and compared several commercial websites of retailers based on the search results and his own identified web sites. As this example shows, popular tasks are usually achieved by web search engines and/or web sites. None of the participants used an online database for popular tasks.

5.1.2. Search task types and tactic selection

In the dataset, three kinds of search task types are identified – subject-oriented search, specific information search, and known-item search. The number of tactics applied in subject-oriented searches, specific information searches, and known-item searches turned out to be 2105, 1427, and 203, respectively. Table 5 shows the cross-tabulation of search task type and tactic selection. A Chi-square analysis rejected the null hypothesis. The findings show that there is a significant relationship between search task type and tactic selection: $\chi^2(20, N = 3735) = 51.589$, $p < 0.01$.

Subject-oriented search tasks contain relatively higher ratios of *EvalR* (12.2%) and *AccB* (12.1%) tactics, which are related to the *iterative search result evaluation* strategy. The *Iterative search result evaluation* strategy represents users' repeated search result evaluation activities to find relevant items (Xie & Joo, 2010b). This result suggests that participants relied on *iterative search result evaluation* strategy in accomplishing subject-oriented search tasks. For example, a participant who wanted to search prehistoric cave art repeated evaluating search results to find some related items: "... creates a query: prehistoric cave art... → ... evaluates search results → clicks and accesses 3rd result (The dawn of prehistoric rock art by James Q. Jacobs) → ... accesses back to Google search results and evaluates them again ... → clicks 2nd result (Prehistoric art by history link 101) → ..." In fulfilling specific search tasks, even though the *EvalI* tactic was applied the most proportionally (22.6%), the difference is small among three types of tasks in *EvalI* tactic application. However, the nature of the task requires participants to evaluate individual items to find the answers. For instance, a participant who searched for two ski hills conditions in Wisconsin visited several related websites and evaluated whether each site provided needed information: "oh this is not...this is a kind of skiers guide in general...", "...they have all kinds of info they do a nice job of updating the daily conditions...", "ok, that gives me what I would need." More data are needed for further investigation. Known-item search tasks involved higher proportions of *Creat* and *Mod* tactics, 6.4% and 4.4% relatively. This indicates that participants were likely to find the targeted item relying on query creation and reformulation. In the think-aloud protocol and log data, a participant searching for the proceedings of Cook County Commissioners relied on creating and modifications of search queries at an OPAC system: "...→ accesses Newberry Library OPAC → (query) cook county board of commissioners → ... → my search seems to have disappeared → ... → (query reformulation) removes 'commissioner' from query and searches catalog..."

Table 5
Cross-tabulation of search task type and tactic selection.

Tactic	Search task type		
	Subject ($N = 2105$) (%)	Specific ($N = 1427$) (%)	Known-item ($N = 203$) (%)
Lead ($N = 121$)	2.9	3.4	5.4
Creat ($N = 149$)	3.2	4.8	6.4
Mod ($N = 101$)	2.5	2.8	4.4
EvalI ($N = 837$)	22.4	22.6	21.2
EvalR ($N = 412$)	12.2	9.4	10.3
Rec ($N = 41$)	1.3	.6	2.0
AccF ($N = 1024$)	26.7	28.9	25.1
AccB ($N = 383$)	12.1	8.3	4.9
Xplor ($N = 385$)	9.8	10.7	12.8
Org ($N = 44$)	1.2	1.1	1.5
Use ($N = 238$)	5.7	7.4	5.9

5.2. User perceived-knowledge level and tactic selection

5.2.1. Familiarity with search topic and tactic selection

The first user characteristic tested was familiarity with search topic. Familiarity with search topic was measured by a five-point scale from "not at all" to "extremely." Table 6 shows cross-tabulation of familiarity with topic and tactic selection. A Chi-square test rejected the null hypothesis and proved a significant association between familiarity with search topic and tactic selection: $\chi^2(40, N = 3735) = 76.873$, $p < .01$; however, the cross-tabulation of familiarity with search topic in five categories (1–5 scale) and tactic selection exhibits curvilinear pattern, so the authors regrouped the five categories into three categories by combing 1 & 2 and 4 & 5. The regrouping reduces the problem of curvilinear pattern, which indicates that participants might not be able to accurately claim their familiarity level.

It was observed that different search tactic patterns corresponded to levels of familiarity with certain search topics. The "familiar group" applied more percentage of *EvalR* (12.2%) compared with other groups. This shows that the participants of this group engaged in more *EvalR* because their previous knowledge on the topic enabled them to make judgments based on the information provided by the result list. The following shows how a participant of the "familiar group" evaluated search results efficiently based on her previous knowledge. "I looked through the Google results and assessed them according to what I needed (i.e., discarded anything that looked commercial and irrelevant) ..."

Conversely, the participants of the group "not familiar" with the search topic applied relatively higher percentage of query-related tactics such as *Creat* (4.5%) compared to the familiar group. One interesting finding is that participants unfamiliar with the topic were likely to use multiple IR systems and create queries for each system. For instance, in the dataset, one participant wanted to know how to remove arsenic from marshlands in Kewaunee, WI using sugar, but was unfamiliar with the topic. He tried search engines (e.g., Google), online database (e.g., ASCE's civil engineering database), Webpages (e.g., epa.gov), and OPAC (e.g., UWM library PantherCat). He created a query in using each of these IR systems.

5.2.2. Familiarity with resources and tactic selection

The relationship between familiarity with resources and search tactic selection was also tested. Since the frequency of participants selecting "a little" was too small, "a little" and "not at all" were combined into one category. Table 7 presents cross-tabulation of familiarity with source and tactic selection. The result of Chi-square test accepted the null hypothesis, $\chi^2(30, N = 3735) = 35.026$, $p = .242$. Statistically, familiarity with resources was not related to the selection of search tactics.

The result shows that participants preferred to use information sources that they are familiar with. Here is a typical example: "I know that the University of Wisconsin Madison has a great study abroad resource website with all the information needed on every study abroad program available to students, so I selected it." The proportions (80%) of "somewhat more (38.3%)" and "extremely (41.7%)" were much higher than the others. Even though type of resources is associated with the selection of search tactics, familiarity with source was not significantly related to tactic selection, because participants in general selected sources that they were familiar with.

5.2.3. Search skills and tactic selection

The relationship between search skills and tactic selection was also examined. Using pre-questionnaire, levels of search skills of participants were considered as a variable in this study. Table 8 shows cross-tabulation of search skills and tactic selection. A Chi-square test rejected the null hypothesis and proved a signification association between search skills and tactic selection: $\chi^2(20, N = 3735) = 66.295$, $p < .01$.

The expert group exhibits unique tactic selection patterns. Most notably, the expert group applied more *EvalR* tactics (17.1%) and *AccB* (11.5%), but fewer *Xplor* tactics (6.2%), which indicates that they relied more on search result evaluation strategy than browsing in using the Web. This reaffirms the findings of previous research that expert users prefer searching to browsing (Palmquist & Kim, 2000; Lazonder et al., 2000). Moreover, the authors observed that expert participants were more willing to use advanced search functions. The following example shows how an expert participant used the advanced

Table 6
Cross-tabulation of familiarity with search topic and tactic selection.

Tactic	Familiarity with topic		
	Not familiar ($N = 1164$) (%)	Intermediate ($N = 1154$) (%)	Familiar ($N = 1417$) (%)
Lead ($N = 121$)	3.6	3.2	3.0
Creat ($N = 149$)	4.5	4.4	3.2
Mod ($N = 101$)	2.7	2.7	2.7
Evall ($N = 837$)	22.8	21.8	22.7
EvalR ($N = 412$)	10.4	10.5	12.0
Rec ($N = 41$)	.8	1.5	1.1
AccF ($N = 1024$)	27.1	28.7	26.7
AccB ($N = 383$)	8.7	10.1	11.7
Xplor ($N = 385$)	11.0	9.2	10.7
Org ($N = 44$)	1.1	1.7	.8
Use ($N = 238$)	7.4	6.3	5.6

Table 7
Cross-tabulation of familiarity with source and tactic selection.

Tactic	Familiarity with source (non-significant)			
	Not at all or a little (*N* = 341) (%)	Somewhat (*N* = 491) (%)	Somewhat more (*N* = 1460) (%)	Extremely (*N* = 1438) (%)
Lead (*N* = 121)	3.5	4.8	3.2	2.7
Creat (*N* = 149)	5.0	4.2	3.8	3.8
Mod (*N* = 101)	3.8	2.8	3.2	1.9
EvalI (*N* = 837)	22.9	22.0	22.2	22.7
EvalR (*N* = 412)	10.3	9.7	12.1	10.6
Rec (*N* = 41)	1.8	1.4	.7	1.3
AccF (*N* = 1024)	27.9	28.8	26.0	28.3
AccB (*N* = 383)	6.2	8.3	11.3	10.8
Xplor (*N* = 385)	10.9	11.7	9.7	10.4
Org (*N* = 44)	.9	1.2	1.4	1.0
Use (*N* = 238)	7.0	5.0	6.6	6.4

Table 8
Cross-tabulation of search skills and tactic selection.

Tactic	Search skills		
	Intermediate (*N* = 883) (%)	Advanced (*N* = 2419) (%)	Expert (*N* = 433) (%)
Lead (*N* = 121)	2.7	3.6	2.5
Creat (*N* = 149)	3.5	4.2	3.9
Mod (*N* = 101)	3.3	2.3	3.9
EvalI (*N* = 837)	23.6	22.2	21.2
EvalR (*N* = 412)	9.7	10.4	17.1
Rec (*N* = 41)	1.1	1.0	1.4
AccF (*N* = 1024)	26.7	28.1	25.2
AccB (*N* = 383)	9.1	10.5	11.5
Xplor (*N* = 385)	9.7	11.2	6.2
Org (*N* = 44)	1.4	.8	2.8
Use (*N* = 238)	9.2	5.7	4.2

search function effectively in his search process: "The homepage has a prominent section 'Lawyer Locator'... I chose the Advanced Search to refine area of law desired & a few other pieces of necessary data... The first search netted 146 hits. I refined this further by 'area of practice' to reduce it to 24... From there I could also limit it to firms in or near Milwaukee, WI." Also, it turned out that the expert group is more likely to use some minor tactics, such as *Org* (2.8%). Conversely, the intermediate group shows lower usage of *EvalR* tactics (9.7%) compared to the other groups.

5.3. Search process

5.3.1. Search session length and tactic selection

The authors grouped 60 cases into four categories based on search session length as shown in Fig. 1 to test whether there is association between search session length and tactic selection. Table 9 presents four groups of cases by time length.

Table 10 shows the cross-tabulation between time length and tactic selection. Null hypothesis was rejected based on a Chi-square test. A significant association between time length and tactic selection was identified: $\chi^2(30, N = 3735) = 61.975$, $p < 0.01$. Each of the four groups presents a unique pattern of tactic selection. Following examples show typical patterns of short search, medium search, and long search, respectively.

First, short searches showed relatively higher percentage of *Creat* (4.3%) compared to long searches, but the least of *Mod* (1.4%) compared to medium-long and long searches. This indicates that participants created initial queries in performing short searches, but did not often modify those queries. Short searches were exemplified by participants finding relevant

Table 9
Four groups of cases by time length.

	By category		
	Num.	M	STD
Short search (⩽11′15″)	17	8′19″	2′47″
Medium short search (12′30″⩽ and ⩽20′45″)	21	16′25″	2′37″
Medium long search (23′45″⩽ and ⩽33′45″)	15	28′1″	3′43″
Long search (35′<)	7	56′19″	17′3″

Table 10
Cross-tabulation of time length and tactic selection.

Tactic	Time length			
	Short (*N* = 559) (%)	Medium		Long (*N* = 588) (%)
		Medium-short (*N* = 1342) (%)	Medium-long (1246) (%)	
Lead (*N* = 121)	3.6	3.1	3.5	2.7
Creat (*N* = 149)	4.3	4.2	4.3	2.7
Mod (*N* = 101)	1.4	2.2	3.7	2.9
EvalI (*N* = 837)	22.0	21.6	22.2	25.0
EvalR (*N* = 412)	10.4	10.3	13.2	8.8
Rec (*N* = 41)	.4	1.2	1.3	1.2
AccF (*N* = 1024)	27.9	28.5	26.5	26.4
AccB (*N* = 383)	9.1	11.4	9.4	10.5
Xplor (*N* = 385)	13.6	10.2	8.5	11.2
Org (*N* = 44)	.7	.7	2.2	.5
Use (*N* = 238)	6.6	6.5	5.4	8.0

items by entering only one query. For example, one participant obtained a recipe for banana walnut bread successfully by creating a query "banana bread" in Google and accessing a relevant item immediately.

Second, two typical types of iterative patterns were found in medium searches: iterative search result evaluation and iterative exploration. These two types of iterative patterns were repeated several times in typical medium searches. The following examples show one iterative search result evaluation and one iterative exploration, respectively.

Creat → (a list of search results) → ***EvalR*** → *AccF* → (an individual item) → *EvalI* → *Use* or fail to use → *AccB* → (the list of search results) → ***EvalR*** → *AccF* → (an individual item) → *EvalI* → *Use* or fail to use → [iteration]

... → [enter an individual item] → *EvalI* → *Use* or fail to use → ***Xplor*** → *AccF (internal or external link)* → (an individual item) → *EvalI* → *Use* or fail to use → ***Xplor*** → *AccF (internal or external link)* → (an individual item) → *EvalI* → *Use* or fail to use → ***Xplor*** → [iteration]

Third, long searches are typically the extension of medium searches. In long searches, more than 10 cycles of the iterative patterns identified above are usually observed within one search session. Also, in long sessions, participants applied the most *EvalI* tactics (5.0%). This shows that participants conducting long search sessions expended more effort in evaluating individual documents of the search results.

5.3.2. Search phases and tactic selection

Search phase is another search process-related factor investigated. Table 11 presents the frequency of and proportions of search tactics at the beginning, middle, and ending phases. The association between search phase and tactic application was investigated by conducting a Chi-square test. The test result rejected the null hypothesis, and it revealed that there is a significant association between selection of search tactics and search phases, $\chi^2(20, n = 3643) = 417.238$, $p < 0.01$.

When examining the beginning six tactics, the authors found that the proportions of *Creat* (16.0%) and *EvalR* (15.4%) were higher at the beginning phase than in the other phases. Most of the beginning sessions included at least one *Creat* tactic. Of 53 cases, only five cases did not include *Creat* at the beginning phase. To be more specific, in more than 90% of the search sessions, participants created a query or queries to get their search tasks started within the first six search tactics. Middle and ending phases showed similar patterns of tactic application; however, the percentage of *Xplor* (7.2%) in ending phases

Table 11
Frequency of and proportions of search tactics at the beginning, middle, and ending phases.

Tactic	Phase		
	Beginning (*N* = 318) (%)	Middle (*N* = 3007) (%)	Ending (*N* = 318) (%)
Lead (*N* = 121)	15.1	2.1	1.3
Creat (*N* = 149)	16.0	2.8	1.9
Mod (*N* = 101)	1.3	3.0	2.2
EvalI (*N* = 837)	12.9	23.1	27.4
EvalR (*N* = 412)	15.4	10.8	8.2
Rec (*N* = 41)	.0	1.2	1.6
AccF (*N* = 1024)	31.1	27.2	24.8
AccB (*N* = 383)	1.6	11.4	9.7
Xplor (*N* = 385)	5.0	11.3	7.2
Org (*N* = 44)	.3	1.1	1.9
Use (*N* = 238)	1.3	6.0	13.8

was lower than that in middle phases. Instead, the proportions of *EvalI* (27.4%) and *Use* (13.8%) were higher in ending phases than those in middle phases. Participants focused more on evaluating and using items in the ending phases. Even though participants of this study did not apply many *Mon* tactics, 9 out of 14 *Mon* tactics observed occurred in the ending phase. Participants of the study monitored their search process more in the ending phase than in other phases.

5.4. System types

5.4.1. System types and tactic selection

System type is the key factor examined for its association with tactic selection. Based on log data, the usage of four types of web-based IR systems was observed – search engines, Web pages, online databases, and OPACs. Table 12 presents the cross-tabulation between system type and search tactic selection. A Chi Square analysis rejected the null hypothesis, $\chi^2(30, N = 3735) = 210.472$, $p < .01$, suggesting that there was a significant relationship between system type and tactic selection.

Search engines, online databases, and OPACs generally led to the application of query-related tactics such as *Creat* (4.1%, 4.2%, and 5.0%), *Mod* (3.0%, 2.8%, and 5.0%), and *EvalR* (11.6%, 13.9%, and 19.3%). Verbal protocol and diary data corroborate the log and questionnaire data. Here are some examples that illustrate the typical patterns of searching different types of IR systems. One of the participants described her pattern of using search engines, "(after entering the query) . . .looking at first five retrievals and click the first result on Google." This typical pattern of using search engines involves *Creat* and *EvalR*. The following example shows how OPACs are associated with search related tactics. "[County Cat (library catalog)] I type in County Cat box, option 'keywords' on drop down box search terms: biometrics, microchip, or digital security (*Creat*); I can skim through it and decide if this is the material I need for this research project (*EvalR*)." For Webpages, *EvaI* (24.8%), *AccF* (29.4%), and *Xplor* (12.8%) were the most frequently applied tactics. *Creat, Mod*, and *EvalR* tactics occurred less often, showing 3.2%, 0.6%, and 5.5%, respectively. The ratio of *Use* (9.1%) in Web pages was higher than in search engines (6.1%), online databases (4.2%), and OPACs (2.8%).

The design of IR systems leads to the selection of different types of search tactics. The authors found that participants selected different search tactics based on the availability and the design of system features. Specific features influenced whether participants employed specific search tactics. In the cases of search engines, online databases, and OPACs, *Creat* and *EvalR* tactics that are related to a query search occurred more frequently than they did in the case of Web pages. Conversely, the ratios of *Xplor* for search engines, online databases, and OPACs were lower than for Web pages. Search engines, online databases, and OPACs usually provide their search functions in a prominent place on the first page. Online databases showed a relatively high ratio of *Org* tactics, accounting for 13.9% because of their search result organizing functions (e.g., sorting and filtering). One participant, who was using an online database system equipped with sorting functions, applied *Org* tactics a couple of times to obtain the optimized search results. Here is one example of verbal protocol in relation to applying *Org* tactics: ". . . looking at results 1–100 and organized by date (Org)." Conversely, limited system features would prevent users from applying certain types of search tactics. As shown in examples below, unavailability of system features leads to not using related search tactics. "There was really no option for sorting (*Not Org*)." "I'm not even aware if MPL (Milwaukee Public Library)'s website has a help feature. . . (*Not Lrn*)."

6. Discussion

A significant contribution of this study lies in uncovering factors that are associated with users' search tactic selections. Eight factors that represent task (work task and search task), user perceived knowledge level (familiarity with topic, familiarity with sources, and search skills), search process (search session length and search phases), and system (system types) were examined in relation to the selection of search tactics. Based on the findings of this study, design implications are discussed. Fig. 2 presents a summary of factors, search tactics, and system design implications. This study suggests that IR sys-

Table 12
Cross-tabulation of system type and tactic selection.

Tactic	System type			
	Webpage ($N = 616$) (%)	Search engine ($N = 2866$) (%)	Online DB ($N = 72$) (%)	OPAC ($N = 181$) (%)
Lead ($N = 121$)	4.9	3.0	2.8	2.2
Creat ($N = 149$)	3.2	4.1	4.2	5.0
Mod ($N = 101$)	.6	3.0	2.8	5.0
EvalI ($N = 837$)	24.8	22.1	19.4	19.9
EvalR ($N = 412$)	5.5	11.6	13.9	19.3
Rec ($N = 41$)	1.5	.9	1.4	2.8
AccF ($N = 1024$)	29.4	27.2	22.2	26.0
AccB ($N = 383$)	6.2	11.0	9.7	12.7
Xplor ($N = 385$)	12.8	10.4	5.6	2.8
Org ($N = 44$)	1.9	.7	13.9	1.7

tems can offer optimal support to users for their selection of search tactic by taking account of different types of factors. An IR system needs to better support users' application of different search tactics based on their tasks and their knowledge levels. Here are the suggestions for IR system design:

- First, since users might select different IR systems for different types of work tasks, the design of an IR system needs to provide different features to support a specific type of work task. Users are likely to use a relatively high proportion of tactics such as *Mod, EvalR* and *Org* in accomplishing scholarly tasks. This indicates that IR systems, such as online databases and OPACs, should enable users to apply various functions to support query reformulation, search result evaluation, and result organization in performing scholarly search tasks. For example, system designers can employ features like presenting relevant meta-information of search results, categorizing results by different topics, and offering different options for sorting search results. For query reformulations, the IR systems can offer multiple query manipulation, secondary window usage, query feedback and suggestions, query and search result tracking, and others (Rieh & Xie, 2006; Kelly, Gyllstrom, & Bailey, 2009). At the same time, users prefer exploring the Web using simply *Xplor* and *AccF* in searching popular tasks. They tend to browse different sites by clicking on URLs. This finding implies that system design for popular tasks, such as Web search engines and Web pages, should focus on the enhancement of browsing functions, such as different options for browsing, and offering task-oriented browsing in addition to subject browsing (Mu, Ryu, & Lu, 2011). In addition, popular tasks also require the application of comparison strategy for some types of specific tasks, such as shopping, and travelling. The incorporation of a comparison mechanism with different criteria that can be selected in these IR systems, as well as linking similar results from different systems can help users quickly find the best items. In cases of occupational tasks, comparatively high proportions of iterative exploration patterns of web pages were observed, so these web pages need to be equipped with functions for supporting iterative browsing, such as well-structured categories of relevant items dedicated to a specific occupational area. For IR systems that users might use for multiple types of tasks, the design needs to consider the incorporation of a variety of features to support different types of work tasks.
- Second, an IR system can offer templates for different types of search tasks. For subject-oriented tasks, in which users intensively apply iterative evaluation, the IR system can focus on facilitating search result evaluation by using well-presented meta-information, categorizing search results by tasks, and sorting search results in different ways. Moreover, the IR system should also focus on enhancing the efficiency of the hub and spoke structure to present search results and related items together to reduce the need to navigate forward and backward (Catledge & Pitkow, 1995; Thatcher, 2006). For specific information search tasks, it is better for IR systems to present quick answers instead of documents to respond to the specific information tasks. For example, Yahoo! Shortcuts Search can help users find specific

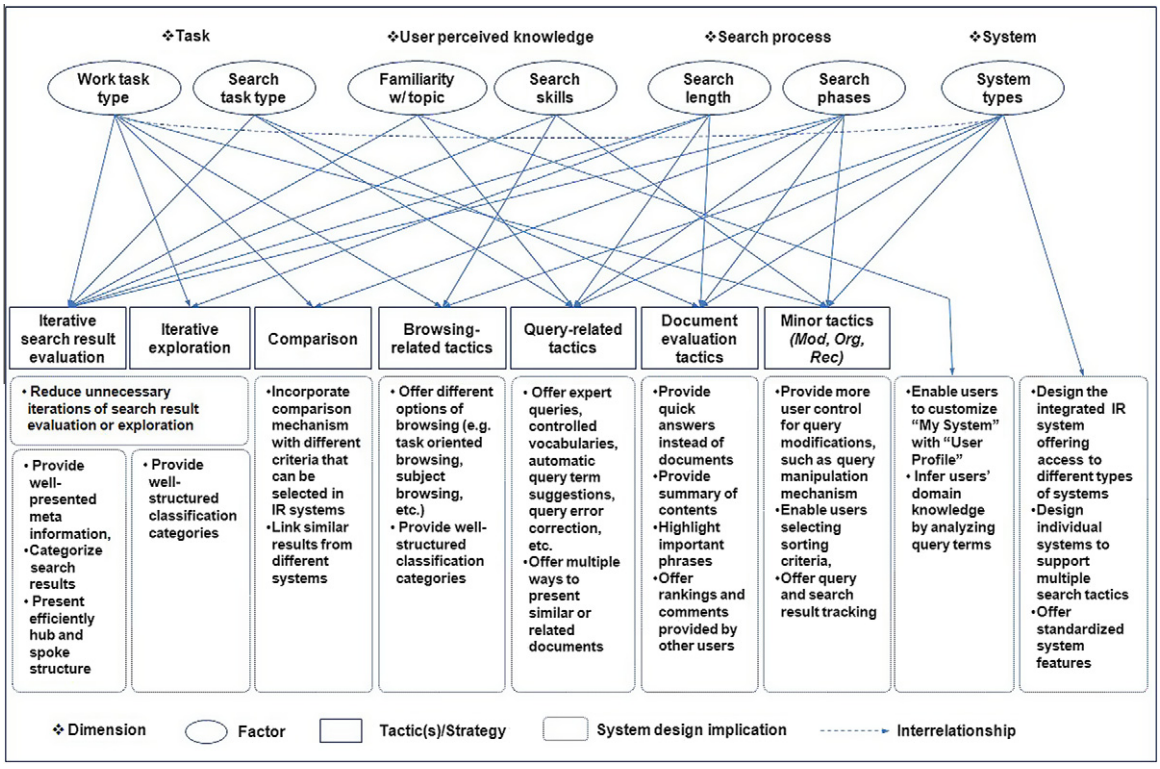

Fig. 2. Summary of factors, search tactics, and system design implications.

information efficiently by using special words and symbols (http://help.yahoo.com/l/us/yahoo/search/basics/basics-05.html). For known-item searching, it is useful to integrate users' personal information systems/space, such as their emails, bookmarks, and personal folders, into IR systems; this can support users in known-item search tasks by helping them access the items easily and quickly.

- Third, familiarity with search topic is closely related to users' domain knowledge. IR systems need to design different features for users with different levels of domain knowledge. One approach to identifying users' levels of domain knowledge is to enable users to customize "My System" so that they can create "User Profiles" including their levels of domain and system knowledge. Another approach is to infer users' domain knowledge by analyzing query terms. If a user enters professional or expert level terms in his/her search queries, a system can infer he/she has expertise in the topic area, and vice versa. This study revealed that users familiar with a search topic would mainly concentrate on evaluating the search results instead of individual documents, whereas users unfamiliar with a topic are more likely to concentrate on query creation and evaluation of individual documents. Thus, a system needs to respond differently to users with different levels of domain knowledge. For users familiar with a topic, systems should provide an enhanced result list with short summary and categorized overviews (Kules & Shneiderman, 2008), since that can facilitate users identifying relevant items easily without examining individual documents. For users unfamiliar with a topic, systems should help them choose appropriate query terms by offering different features, such as recommending expert queries and controlled vocabularies, providing automatic query term suggestions, and finding documents like this one. In addition to evaluation features for search results, it is also useful for IR systems to offer best passages of individual documents, so users can quickly make relevance/usefulness judgments.
- Fourth, as to users' search skills, it turns out expert users more frequently use *EvalR,* advanced searches, and *Org*. It is important to design IR systems to support both user control and ease-of-use. The design implication for *EvalR* is discussed in the suggestion for supporting subject search tasks above. In spite of a simplified interface and features for novice users, the design of the more advanced features of query formulation and reformulation as well as result organization will enable expert users to manipulate their queries and search results, and integrate them into their own works. One option is to allow them to use special commands to construct more specific queries. Another one could be related to enabling users to come up with their own sorting criteria. More advanced features for other types search activities are also helpful.
- Fifth, medium searches consist of iterative patterns of search result evaluation and exploration, and long searches show relatively more efforts in item evaluation. These results lead to the following design suggestions. For medium searches, system design should pay attention to reducing unnecessary iterations of search result evaluation or exploration, as discussed in supporting subject-oriented tasks above. In order to support effective document evaluation, the system should support the evaluation activities of users, such as highlighting key points, providing most relevant paragraphs and summaries, and offering rankings and comments specified by other users.
- Sixth, three sequential search phases – beginning, middle, and ending – present different patterns of search tactic selection. As expected, *Creat* tactics were the most important tactics applied by participants to get a search session started. More than 90% of search sessions had at least one *Creat* tactic in their beginning phases. To support the starting phases with query creation, a system can be equipped with query creation aid functions such as basic and advanced search, query error correction, query suggestions, and controlled vocabularies. Middle phases involved many iteration patterns of evaluating search results and exploration. Again, system design is related to reducing unnecessary iterations of search result evaluation or exploration, as discussed in supporting subject-oriented tasks above. During ending phases, relatively high percentage of *EvalI* was observed. System design can offer the options of display document according to different types of search tasks, such as highlighting key fields for known item searches, extracting key data/information for specific information searches, and presenting best passages for subject searches. Since *Use* occurred most frequently at the ending phase, it is helpful for IR systems to enable users to integrate their searches into their work spaces.
- Seventh, users applied different search tactics in different types of IR systems/resources. In searching search engines, *Creat*, *Mod*, *EvalR*, and *AccF* consisted of 91.4% of applied search tactics. Also, online databases and OPACs showed higher percentage of *EvalR* as well as lower percentage of *Xplor*. Webpage users, however, frequently applied exploration strategies using *EvalI*, *AccF*, and *Xplor*, but less frequently applied iterative search results evaluation strategies. The results suggest two possible approaches to information system design: (1) an integrated system for different types of information sources and (2) an individual system that supports all possible search tactic applications. The integrated system offers common access to different types of sources, such as web materials, online databases, and library resources, simultaneously in one consolidated system. Using this integrated approach, the system could offer various information sources to users. Also, the integrated system would allow users to compare search results from different sources since it could present the results from different systems. Moreover, once a user was to learn how to use the integrated system, he/she would not need to make an effort to learn different individual systems. Another approach is to enhance individual systems to support multiple search tactics during search processes. IR systems need to support tactics in relation to query creation and modification, as well as search tactics that are in relation to exploration, organization, monitoring, evaluation, etc. For example, although users tend to select browsing-related tactics in using individual web pages, these web pages still need to provide strong search functions to help users apply search-related tactics. Although users rely more on search-related tactics in online databases and OPACs, they still have a need for browsing items. Moreover, system design needs to better support users in evaluating search results and individual documents and organizing search results by different criteria discussed above. In addition, IR systems need to allow users to know where they are and how they get

there. Thus, individual systems need to support multiple tactics in different types of systems. Further, if standardized features were provided over different types of systems, it could assist users to use different systems with less effort in learning each system.

This study has some limitations. First, 31 participants might not be able to represent the general public, even though the study analyzed 3788 tactics observed in 60 search sessions. Second, think-aloud protocols were useful to capture verbalization of participants' thoughts, but they might not grasp all complicated thoughts during their search processes. Third, this study was based on the analysis of data generated from one search session. That might lead to the loss of realism, since, in reality, users could engage in multiple search sessions in order to accomplish their search tasks. Fourth, the eight factors that are statistically examined in this study might not be sufficient to understand users' tactic selection behaviors. Obviously, there are more relevant factors that are not mentioned in the present paper. Fifth, the authors were unable to conduct multivariate analysis, in particular multiple regression, to test and identify potential interactions among factors affecting the use of search tactics because of the limitation of the data, e.g., frequency of search tactics and categorical data of some of the factor variables. Further research is discussed in the conclusion to respond to the limitations of this study.

7. Conclusion

The study investigated users' search tactic selection and associated factors in achieving their real tasks. The main contribution of this study can be summarized as follows. (1) This study did not focus on one type of search tactic as many of the prior studies did; instead, it explored multiple search tactics that are applied during the search process. (2) This study examined factors in relation to multiple dimensions, including tasks, user's perceived knowledge, search process and system types, and their relationships with search tactic selection. (3) This study not only statistically tested the association between factors and search tactic selection, but also discovered in what ways these factors influence the selection of search tactics. (4) The implications of system design are systematically discussed corresponding to findings of this study.

Considering the limitations of this study addressed above, further research is needed to generalize the results and enhance the study. Next, the authors will expand this study to more participants with a variety of tasks in real settings to better generalize the results. Foremost, future research should not be limited to search tactics applied in users' interaction with Web-based IR systems. Instead, it should extend to all the tactics applied in users' interactions with all types of resources, including human resources and printed materials in the search process. This will enable the design of better IR systems to integrate all different resources. In addition, more factors that would potentially influence search tactic selections will be included in the future study. There are a number of potential factors not covered fully in the present study, such as task difficulty, task urgency, age, job, search stage, help system, and others. Future studies will cover a variety of factors more extensively to portray the entire picture of search tactic selection in diverse information environments. Finally, future research also needs to investigate interaction effects among factors by using multivariate statistical analysis. In order to conduct multivariate statistical analysis, the dependent variable, tactic selection, has to be measured by a continuous scale. The investigation of how different factors affect the selection of search tactics will greatly help researchers understand the nature of information retrieval process and designers enhance the design of IR systems.

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