

Article

Tales from the Field: Search Strategies Applied in Web Searching

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Abstract: In their web search processes users apply multiple types of search strategies, which consist of different search tactics. This paper identifies eight types of information search strategies with associated cases based on sequences of search tactics during the information search process. Thirty-one participants representing the general public were recruited for this study. Search logs and verbal protocols offered rich data for the identification of different types of search strategies. Based on the findings, the authors further discuss how to enhance web-based information retrieval (IR) systems to support each type of search strategy.

Keywords: search strategies; search tactics; web environment; IR system design

1. Introduction

Search strategy is one of the major topics in interactive information retrieval (IR) studies, and many researchers have tried to identify various search strategies in the contexts of different tasks and situations. In a broad sense, a search strategy refers to a plan for a search task [1]. When users conduct information searches, they must have some search strategies that are a combination of the choice of terms, operators, and tactics [2]. Search strategies are the products of planned or situational interactions between users and IR systems. A search tactic refers to a single movement or an action to achieve specific objectives in the information searching process, while a search strategy highlights a working plan and interactive reaction for a given situation. A search strategy consists of a series of

sequential tactics that take into account both planned and situational elements [3]. Our study adopts this definition of search strategy and considers sequential tactics as the major component of a search strategy.

Search strategies in the web environment imply more possible interactions between users and IR systems than traditional searching environments. Working with web interfaces, users apply various types of tactics such as typing URLs, moving forward and backward, query formulation, scanning websites, following links, searching known addresses, saving documents, *etc.* [4–7]. In the web environment, users incorporate various chains of search tactics and then formulate strategies to achieve search goals or tasks efficiently and effectively. However, web IR systems do not effectively support users in applying tactics to formulate search strategies. Compared with traditional IR systems, web IR systems offer a simplified and easy environment for users that requires different types of cognitive involvement. Web IR systems here refer to any IR systems that users can access and use on the web, including but not limited to web search engines, online databases, online public access catalogs (OPACs), digital libraries, *etc.*

The IR process is complicated and dynamic, as is the application of search strategies, which consists of multiple types of search tactics. In order to understand the dynamic search strategies, researchers need to look into the sequential patterns of search tactics. In web searching, users build search strategies by selecting a series of search tactics, such as creating a query, clicking hyperlinks, and evaluating the relevance of an item. Many researchers have paid attention to identifying types of search strategies during the information searching process. However, little research has generated search strategies based on the analysis of sequential tactics applied in the web environment. Most of the prior research on search strategies focused on query-related tactics [8–10], illustrated search strategies at conceptual levels [11], or chose specific user groups, such as engineers or scientists [12].

In order to identify types of search strategies, there is a need to explore sequential patterns of search tactics empirically by investigating real users' search behaviors in accomplishing their real tasks in the web-based search environment. This study intends to identify different types of search strategies based on the analysis of real users' sequences of search tactics in achieving their real tasks. The findings of this study help researchers better understand how users develop their search strategies. The identification of search strategies offers implications for IR system design to support different types of search strategies.

2. Literature Review and the Research Question

Searching behaviors can be discussed at two levels based on their units of analysis: search tactics and search strategies. Previous research on these two levels of search behaviors is reviewed here. Search tactics have been important topic in information searching because they are essential and fundamental components of the search process. Since researchers have used tactics and moves interchangeably, the authors also include related studies on moves in the literature review. In an early study, Bates [1] identified a set of 29 information tactics, and classified these 29 tactics into monitoring, file structure, search formulation, and term tactics. Most researchers have focused on query formulation and reformulation in analyzing search tactics. Fidel [8] differentiated the operational and conceptual moves that either keep or change the meaning of a query in the query reformulation

process. While operational moves are characterized by reducing or enlarging the size of search results, conceptual moves are exemplified by intersecting, narrowing, or expanding the meaning of queries. Shiri and Revie [13] identified cognitive moves in which users perform some kind of conceptual analysis of terms or documents and physical moves that are associated with the use of system features. Shute and Smith's [14] knowledge-based tactics are associated with query reformulation, in particular, topic refinement. Vakkari, Pennanen, and Serola [2] also identified query search-related tactics, such as searching for an author, terms checks, *etc.*

A series of search tactics constitute search strategies, which are a complex number of tactics that involve both information domains and modes of seeking [15]. Markey and Atherton's [11] work is one of the initial findings of search strategies named as building-block, pearl-growing, successive-reactions, most-specific first, and lowest postings-facet first, which are the most frequently cited strategies in the field. Hawkins and Wagers [16] identified one of the frequently used strategies as "interactive scanning" that highlighted user interactions with systems. Also they addressed the usefulness of the strategy when a user is not familiar with the topic and needs high recall. Focusing on cognitive aspects of search strategies, Chen and Dhar [17] identified five types of strategies: the known-item instantiation strategy, the search-option heuristic strategy, the thesaurus-browsing search, the screen-browsing strategy, and trial-and-error strategy. Marchionini [18] summarized search strategies into two essential levels of categories: analytic and browsing strategies. Analytic strategies indicate goal-oriented and systematic, while browsing strategies are more informal and interactive. Another type of search strategy is in relation to feedback, and Spink and Saracevic [19] suggested five types of interactive feedback in relation to interactive IR.

After the emergence of the internet, researchers began to find new types of search strategies in the web-based information environment. Hawk and Wang's [7] problem-solving strategies reflect the hyperlink and search function characteristics of the web environment including various strategies, such as surveying, double-checking, exploring, link-flowing, back-and-forward-going, shortcut-seeking, engine-using, loyal-engine-using, engine-seeking, and meta-searching. Drabenstott [20] investigated the differences of search strategies applied by non-domain experts and domain experts. Based on a survey of 234 web users, Aula, Jhaveri, and Kaki [4] found frequently used key strategies, such as opening multiple tabs and information re-access strategy. Thatcher [6,21] identified 12 cognitive search strategies that include safe player, parallel player, link dependent, to-the-point, known address, sequential player, deductive reasoning, and secondary search. Search strategies were also generated from search log data. Wildemuth [22] found that the specification of a concept and adding more concepts was the most common strategy during the medical students' database searching process. Wolfram *et al.* [9] discovered three types of strategic patterns from the large scale log data in the web search environment, including academic websites, public search engines, and consumer health information portals. Similarly, Jansen *et al* [10] investigated query reformulation strategies during web searching by exploring the patterns of query transitions derived from the large scale log data.

Previous research has identified various types of tactics and strategies in different search environments. In particular, a variety of types of search strategies were identified from the empirical observations of web users. These studies have greatly helped researchers and system designers understand the complicated information search process. However, previous research of search strategies has not associated search tactics with search strategies. Even though many researchers

assume that search strategies are constituted by a series of tactics, few have analyzed the tactic patterns in detail in order to find patterns of search strategies. In addition, a large portion of related studies concentrated more on query formulation and reformulation in finding search strategies. Moreover, many of the strategies were discovered from the data of convenience samples and assigned tasks as opposed to real users with their real problems. The limitations of previous research call for the need to identify search strategies from the analysis of search tactics involving real users with their real problems. This study intends to answer the following research question: What are the types of search strategies applied by users during web searching based on the analysis of sequential tactic data?

3. Methodology

Thirty-one participants from the Greater Milwaukee area were recruited in the study after responding to fliers or newspaper advertisements. They represented general users of information with different gender, race, and ethnic backgrounds, education and literacy levels, computer skills, occupations, and other demographic characteristics. This study intends to investigate general public users with their real problems, so researchers asked users to select their own search tasks for the study. Each participant was asked to conduct two self-generated tasks instead of assigned tasks. However, two out of 62 tasks could not be analyzed because of poor quality of the recorded data, thus the total number of tasks being analyzed in this study was 60. 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%
	English	29	93.5%
Native Language	Non-English	2	6.5%
	Caucasian	29	93.5%
Ethnicity	Non-Caucasian	2	6.5%
	Expert	3	9.7%
Computer Skills	Advanced	21	67.7%
	Intermediate	7	22.6%
	Beginner	0	0.0%

Multiple data collection methods were applied to collect data. Thirty-one participants were invited to come to the Information Intelligence & Architecture (IIA) research lab at the School of Information Studies at the University of Wisconsin-Milwaukee (UWM-SOIS) to search for information for two of their own tasks: one work-related and another one personal-related. They were instructed to “think aloud” during their search processes. Their information search processes were captured by Moraes, a

usability testing software that not only records users’ movements, but also captures their “think aloud,” including their feelings, thoughts, and intentions during the search process. Log data and think aloud data were the main sources of analysis for this study. In addition, participants were instructed to fill in a pre-questionnaire soliciting information in relation to their demographic information and their experience in using different types of IR systems and a post-questionnaire soliciting information in relation to their search activities and problems.

This study also considers the effect of search tasks, which represent a task that determines what a user is searching for [23–25], on selection of search strategies. Researchers found that search task is one of the key factors affecting information seeking strategies [23,26–30]. Based on Xie’s [30] identification of search tasks, three types of search tasks, including known item search, specific information search, and subject search, were identified. For better understanding of the study, Table 2 shows examples of each search task type from our dataset. Since the authors are working on another paper examining factors affecting search tactic transitions and applications of different types of search strategies as well as the space limitation, the results of the effect of search tasks on types of search strategies are not reported in this paper.

Table 2. Types of search tasks and examples.

Types of search tasks	Examples
Known-item search	“I want to know if the UW-Milwaukee library has a copy of the book ‘ <i>History of Racine and Kenosha Counties from 1879</i> ’. I expect to determine whether or not the library has the book.”
Specific information search	“I’d like to find out the conditions of two local ski hills.”
Subject search	“I want to learn more about both the positive and negative effects that caffeine has on the body.”

The identification of types of search strategies was based on the analysis of sequences of search tactics. In order to investigate the search tactics and their sequential patterns, the authors employed a coding scheme for search tactics developed mainly by Xie [3]. The coding scheme consists of 13 types of tactics (Table 3). The authors were able to code think aloud protocols, as well as search logs using the scheme. For simplicity, each tactic has been represented by an acronym and italic font was applied to the acronym.

After coding each of the search tactics for every participant’s search process, patterns of search tactics were analyzed to generate search strategies. The transitions between tactics were co-determined by log analysis and verbal protocol analysis. Each move was identified and associated with its previous and following move to see whether a participant changed his/her search tactics based on the coding scheme. In addition, verbal protocols corresponding with each move were analyzed to assist the coding. When a change of search tactic was identified, the transition of search tactic was recorded. The authors [31] examined the transitions in search tactics by applying different orders of the Markov models. Content analysis was applied to find out meaningful strategic tactic sequences during the search episode. First, frequently occurring sequences of tactics were identified. Second, the objectives of these sequences were analyzed to determine whether the sequences were meaningful enough to be considered a strategy, such as enhancing precision or recall for multiple query reformulation strategy,

compare items with common characteristics from multiple sources for item comparison strategy, *etc.* By analyzing the participants’ activities from logs and think-aloud protocols, the authors were able to code search activities into search strategies by using 13 types of tactics. In this way, eight strategies were identified from the analysis of tactic transition patterns. After that, the authors named and defined each type of search strategy including a series of tactics.

Table 3. Coding Scheme of Types of Search Tactics.

Code	Types of Search Tactics	Definitions	Examples
<i>Lead</i>	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”
<i>Creat</i>	Creating search statement	Come up with a search statement for searching	[type in] “I am going to search <i>pea shoots</i> ”; [using a given form] “fill fields with date and time to query what is available”
<i>Mod</i>	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”
<i>EvalI</i>	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.”
<i>EvalR</i>	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.”
<i>Rec</i>	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.”
<i>AccF</i>	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”
<i>AccB</i>	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”
<i>Lm</i>	Learning	Gain knowledge of system features, system structure, domain knowledge, and database content	“Learn how to use Google earth”

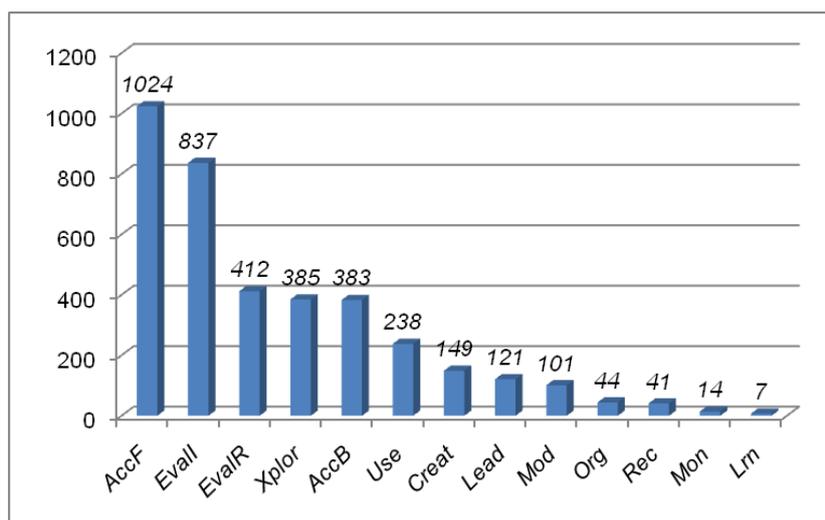
Table 3. Cont.

Code	Types of Search Tactics	Definitions	Examples
<i>Xplor</i>	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”
<i>Org</i>	Organizing	Sort out a list of items with common characteristics	“sorted results by length of antenna”
<i>Mon</i>	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.”
<i>Use</i>	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.”

Search strategies were analyzed at three levels: categories of search strategies, types of search strategies, and variants of search strategies. Types of search strategies specifies different sequences of search tactics to achieve some goals, such as compare items, reformulation queries, get started, explore a site, *etc.* Search strategies that share similar characteristics were grouped together as categories of search strategies. At the same time, each type of search strategy also contains its variations. To save space, examples and results of each category, types and variations of search strategies were reported in the Results section.

In order to ensure the reliability of data coding, one researcher first coded the data using the coding scheme presented above and analyzed sequences of search tactics, and then another researcher analyzed and verified whether the coding was appropriate. If there were disagreements in the coding, the two researchers worked together to reach an agreement.

Figure 1. Frequency of types of search tactics applied.



A total of 3,756 tactics were observed in 60 search tasks performed by 31 participants. The number of search tactics varied by search session. A minimum value was 7; a maximum value was 162. An overall average of search tactics per session was 62.60, and standard deviation was 36.72. Figure 1 presents the frequency of types of applied search tactics. Every type of search tactic was included in the eight types of search strategies.

The first six tactics were selected to analyze starting strategies. In a separate paper, Xie and Joo [31] investigated transitions of tactics at the 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, are considered to be appropriate to identify common patterns of starting strategies in this study.

4. Results

Eight types of search strategies were identified based on the analysis of sequential search tactics, and these eight types of search strategies can be grouped into five categories. Table 4 presents categories of search strategies and corresponding types of search strategies as well as frequency and percentage of the cases that employed each type of strategy. In addition, variations of each type of search strategy are also discussed below.

Table 4. Frequency of and percentage of strategies (N = 60 cases).

Types of categories	Types of strategies	Frequency	Percentage
Search result evaluation	<i>Iterative result evaluation</i>	47	78.3%
	<i>Iterative exploration</i>	45	75.0%
Exploration	<i>Whole site exploration</i>	4	6.7%
	<i>Multiple query reformulation</i>	15	25.0%
Query reformulation	<i>Simultaneous multiple resource search</i>	6	10.0%
	<i>Item comparison</i>	7	11.7%
Simultaneous multiple resource access	<i>Query initiation</i>	53	88.3%
	<i>Known-item initiation</i>	7	11.7%

In the following discussion, the authors used quotations to cite participants’ verbal protocols, [] to add notes of their activities, () to indicate search results or an individual item, and {} to represent optional tactics in a variant pattern.

4.1. Search Result Evaluation

Search result evaluation is the main focus of the search process for participants of this study. *Iterative search result evaluation* strategy was the most frequently applied strategy, accounting for 78.3% of all the cases. It is one of the two strategies that are dominant in web-based information searching processes.

Iterative Result Evaluation

Iterative result evaluation refers to a strategy in which participants evaluated search results repeatedly to access and to find relevant information until they were satisfied or they quit. This strategy was one of the most frequently applied strategies in the web-based information searching process. It is common that search results are displayed in the order of relevance, and participants were likely to evaluate the search result list from the top and access an item based on the evaluation of the title and other meta-information from the search results. When a participant was not satisfied with the item visited, he/she accessed back to the search results and evaluated the rest of list again to find relevant items. This kind of evaluation could be conducted iteratively until participants found satisfactory information or quit evaluation. In this strategy, *EvalR*, skimming search results quickly, is the most important tactic. *EvalR* occurs iteratively and it determines whether any item is worth selecting for detailed evaluation (*EvalI*). Then, *AccF* and *AccB* are also the frequently applied tactics to access or go back to the search result iteratively. The following sequence presents the typical series of tactics and an example (Table 5) of this type of search strategy:

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]

Table 5. Iterative result evaluation strategy.

Tactic	Activities
<i>AccF</i>	[types Google URL]
<i>Creat</i>	[query: calcium rich foods]
<i>EvalR</i>	[clicks 1st result: (title) Calcium rich foods]
<i>AccF</i>	(pediatrics.about.com)
<i>EvalI</i>	[looks at the site]
<i>AccB</i>	[clicks back button to Google]
<i>EvalR</i>	[clicks 3rd result: Calcium-rich foods Nutrition Prevention About osteoporosis]
<i>AccF</i>	(iofbonehealth.org)
<i>EvalI</i>	[looks at website] “...so vegetables...kale has a very high calcium content never have eaten that...baked beans are high in calcium”
<i>Use</i>	“it did give me some info.”
<i>AccB</i>	[clicks back button to Google]
<i>EvalR</i>	[clicks 4th result: MyPyramid.gov]
<i>AccF</i>	(mypyramid.gov)
<i>EvalI</i>	[looks at the site]
<i>AccB</i>	[clicks back to Google]
<i>EvalR</i>	[clicks 3rd result: Calcium-rich foods Nutrition Prevention About osteoporosis]
<i>AccF</i>	(iofbonehealth.org)
<i>EvalI</i>	“It’s the International Osteoporosis Foundation that’s probably one of the better.”
<i>Use</i>	“it looks like the red kidney beans are high in calcium...oh that is interesting eggs are really high in calcium.”
<i>AccB</i>	[clicks back button to Google]
...	...

Along with the typical pattern of this strategy, several variants of *iterative result evaluation* were observed associated with some less frequently occurring tactics such as *Org*, *Rec* and *Mon*. For example, a participant monitored his/her iterative search result evaluation process at the end of a search session. In another case, *Org* and *Rec* tactics were incorporated into the *iterative search result evaluation* strategy. The following pattern showed variants observed in the study:

$Creat \rightarrow (\text{a list of search results}) \rightarrow EvalR \rightarrow AccF \rightarrow (\text{an individual item}) \rightarrow EvalI \rightarrow Use \text{ or fail to use}$
 $\rightarrow \{Org, Rec\} \rightarrow AccB \rightarrow (\text{the list of search results}) \rightarrow EvalR \rightarrow AccF \rightarrow (\text{an individual item})$
 $\rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow \{Org, Rec\} \rightarrow \{Mon\}$

4.2. Exploration

Exploration consists of *iterative exploration* and *whole site exploration* strategy. *Iterative exploration* is another key strategy that dominates the search process, accounting for 75% of the cases while *whole site exploration* occurred less frequently. Although these strategies show similar patterns in tactic sequences, the scopes of these strategies are different. The former one covers both internal and external links of one specific site and goes beyond the site while the latter one restrains to all the internal content within one specific site.

4.2.1. Iterative Exploration

Iterative exploration refers to a strategy in which participants browsed and evaluated a series of items mainly using hyperlinks until they were satisfied or they quit. As with *iterative result evaluation*, this strategy was frequently observed in this study. This strategy indicates browsing to seek related, linked or external items which can be accessible from the current site. It is closely related to browsing the related hyperlinks to identify relevant items on a specific topic. Owing to hyperlinks within the web, *iterative exploration* strategy enables participants to survey different internal and external links to fulfill their information needs. In this strategy, a key search tactic is the *Xplor*. The following present the typical sequence of tactics and an example (Table 6) of this type of search strategy:

$\dots \rightarrow [\text{enter an individual item}] \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow Xplor \rightarrow AccF (\text{internal or external link}) \rightarrow (\text{an individual item}) \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow Xplor \rightarrow AccF (\text{internal or external link}) \rightarrow (\text{an individual item}) \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow Xplor \rightarrow [\text{iteration}]$

Similar to *iterative result evaluation*, this strategy could be extended to different variants involving less frequently applied tactics, such as *Org*, *Rec* and *Mon*. The following pattern of variation was found in the dataset:

$\dots \rightarrow [\text{enter an individual item}] \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow Xplor \rightarrow AccF (\text{internal or external link}) \rightarrow (\text{an individual item}) \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow \{Org, Rec, Mon\} \rightarrow Xplor \rightarrow AccF (\text{internal or external link}) \rightarrow (\text{an individual item}) \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow \{Org, Rec, Mon\} \rightarrow Xplor \rightarrow [\text{iteration}]$

Table 6. Iterative exploration strategy.

Tactic	Activity
...	...
<i>AccF</i>	(www.spacewar.com)
<i>EvalI</i>	[looks at the site: Military Space News, Nuclear Weapons, Missile Defense]
<i>Xplor</i>	[reads further to different page within site]
<i>AccF</i>	(Report: Iran intel turnabout hinged on military notes)
<i>EvalI</i>	[reads the article]
<i>Xplor</i>	(scans the site)
<i>AccF</i>	“North Korean Nuclear declaration must be credible...”
<i>EvalI</i>	[reads the article carefully]
<i>Use</i>	[Reads through the article for about 19 minutes]
<i>Xplor</i>	[from this page the participant looks at related links at the end of the article]
<i>AccF</i>	[clicks the link] “... learn about nuclear weapons doctrine and defense.”
<i>EvalI</i>	[a page that is all advertisements and is not relevant]
<i>AccB</i>	[backs to original page]
<i>Xplor</i>	[finds a link to another article]
<i>AccF</i>	(Article: Bush under fire over Iran claims)
<i>EvalI</i>	[looks at “Bush under fire over Iran claims” article]
<i>Xplor</i>	(link at the bottom for an article “Iran builds new longer-range missile”)
<i>AccF</i>	(Article: Iran builds new longer-range missile)
<i>EvalI</i>	[looks at “Iran builds new longer-range missile”]
<i>Use</i>	[reads the whole article]
<i>Xplor</i>	[goes to another page]
<i>AccF</i>	(Article: “Iran builds new longer-range missile”)
<i>EvalI</i>	[skims the article]
<i>Use</i>	[and reads the article thoroughly for about 20 min]
<i>Xplor</i>	[scrolls down page and looks at other ‘missile news’ articles]
...	...

4.2.2. Whole Site Exploration

Whole site exploration refers to a strategy that participants browsed and evaluated most of the information available in one specific source. This strategy was observed when participants looked through every page in a specific web site to find what they were interested. Four cases of *whole site exploration* strategy occurred in this study. Comparing with *iterative exploration* strategy, the uniqueness of this strategy is that participants repeated exploring until looking through all the information on a website. In addition, they were also limited to the internal materials of the site. Like the *iterative exploration* strategy, *Xplor* is a core search tactic in this strategy. Using this strategy, a participant could gather entire contents of information that were presented on one specific site. The following present the typical sequence of tactics and an example (Table 7) of this type of search strategy:

[enter a web site]→*EvalI*→*Use* or fail to use→*Xplor*→*AccF* (*internal link*)→(an individual item) →*EvalI*→*Use* or fail to use→*Xplor*→*AccF* (*internal link*)→(an individual item)→*EvalI*→*Use* or fail to use→*Xplor*→[iteration until looking through most of the internal links of a specific site]

Table 7. Whole site exploration strategy.

Tactic	Activity
<i>AccF</i>	(londonenglandtours.net)
<i>EvalI</i>	[reads about tours throughout the website]
<i>Xplor</i>	“popular activities...bus tour”
<i>AccF</i>	[clicks link: All around London hop on & hop off Double Decker bus tour]
<i>EvalI</i>	“this is an interesting website”
<i>Xplor</i>	“total London experience”
<i>AccF</i>	[clicks link: Total London experience tour with pub lunch]
<i>EvalI</i>	“this is a good one too”
<i>Use</i>	[reads the page] “cost is much higher than the other one...this is interesting...ok”
<i>Xplor</i>	“what else...historic and modern London tour”
<i>AccF</i>	[clicks link: Historic & modern London tour]
<i>EvalI</i>	“...hmm” (quickly looks for other page)
<i>Xplor</i>	“medieval banquet...”
<i>AccF</i>	[clicks link: Medieval banquet in London]
<i>EvalI</i>	“that’s something different...”
<i>Xplor</i>	“Oxford, Stratford....”
<i>AccF</i>	[clicks link: Oxford, Stratford & Warwick Castle tour from London]
<i>EvalI</i>	“this is something interesting”
<i>Use</i>	“this can be the second day tour... this is a good one”
<i>Xplor</i>	“what else...here is a rock and roll mini bus tour”
<i>AccF</i>	[clicks link: Rock’ N Roll Legends minibus tour...]
<i>EvalI</i>	(quickly scans the item)
<i>Xplor</i>	“...lets see anything else...ah probably this is about the Beatles”
...	...

4.3. Query Reformulation

Query reformulation is an essential search tactic in the search process. *Multiple query reformulation* strategy is another frequently used strategy, especially in obtaining broader or narrower search results. About one-fourth of the sixty cases employed *multiple query reformulation* strategy.

4.3.1. Multiple Query Reformulation

Multiple query reformulation refers to a strategy in which a participant modified an initial query several times continually to obtain the search results that satisfied her/him. Basically, users can make search queries broader, narrower, or parallel by applying this strategy. Query modification represents the dynamic interactions between users and IR systems, and the different types of patterns of query modifications that have been identified in several previous studies [10,32–35]. This study does not investigate the types of query reformulation themselves in detail, but it looks into the patterns of query modification tactics and their relationships to other search tactics. In this study, participants changed their queries several times in order to narrow, broaden, or correct queries in an effort to obtain better search results. Query modification was one option participants took when they were not satisfied with their search results. *Multiple query reformulation* strategy consists of the following key tactics:

$Mod \rightarrow EvalR \rightarrow AccF \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow AccB \rightarrow$. The following present the typical sequence of tactics and an example (Table 8) of this type of search strategy:

$\dots \rightarrow Creat \rightarrow EvalR \rightarrow AccF \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow AccB \rightarrow Mod \rightarrow EvalR \rightarrow AccF \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow AccB \rightarrow Mod \rightarrow EvalR \rightarrow AccF \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow AccB \rightarrow Mod \rightarrow \dots$

One variant of *multiple query reformulation* strategy involves *Rec* tactic. When searching for a book in “amazon.com”, a participant (S28) wrote down book titles after evaluating the search results to keep and compare the findings generated by different queries. Since *multiple query reformulation* strategy usually leads to different search results, users need to keep a record of different search results by applying *Rec* tactic. Here is a pattern of variation found in the dataset:

$\dots \rightarrow Mod \rightarrow EvalR \rightarrow \{Rec\} \rightarrow AccF \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow AccB \rightarrow Mod \rightarrow EvalR \rightarrow \{Rec\} \rightarrow AccF \rightarrow EvalI \rightarrow Use \text{ or fail to use} \rightarrow AccB \rightarrow Mod \rightarrow \dots$

Table 8. Multiple query reformulation strategy.

Tactic	Activity
...	...
Creat	[types a query: 2008 IT job market outlook]
EvalR	“I am not sure which one is the most relevant”
AccF	[clicks 4th result: money magazine 2008 outlook: money.cnn.com]
EvalI	“oh this is CNN money ...this is last year 2007”
AccB	[clicks back to Google]
Mod	“I think I am going to refine (search) for Wisconsin Milwaukee” [query: IT job market outlook Milwaukee]
EvalR	“manpower: bucking national outlook Milwaukee area hiring to grow”
AccF	[clicks 4th result]
EvalI	“this one looks like a professional....outlook 2008 March 11”
Use	[reads the article] “OK these are the official results from Manpower...this is good info”
AccB	[clicks back button to Google]
Mod	“I am typing information technology” [query: information technology job market outlook Milwaukee]
...	...
Mod	[query: information technology job outlook Milwaukee]
...	...
Mod	[query: information technology job Milwaukee]
...	...
Mod	[query: top information technology jobs in Milwaukee]
...	...
Mod	[query: database data warehouse job in Milwaukee]
...	...

4.4. Multiple Resource Access

In this study, participants had to access multiple resources to fulfill their search tasks. Multiple resource access consists of *simultaneous multiple resource search* and *item comparison* strategy.

These two strategies were applied in about 10% and 11.7% of the sixty cases respectively. Different objectives of these two strategies make them each unique in its own way. While *simultaneous multiple resource search* focuses on obtaining relevant and useful information efficiently from different types of sources, *item comparison* concentrates on comparing the information covered by similar sources.

4.4.1. Simultaneous Multiple Resource Search

Simultaneous multiple resource search refers to a strategy that participants utilized multiple web sources simultaneously to achieve one search task. Participants frequently opened multiple windows to obtain information from different information sources. By accessing more than two web resources at the same time, participants could obtain various items efficiently on the same or related search topics. The sequence of search tactics was not likely to be generalized in this strategy, because participants applied different approaches to different resources. Thus, tactic transitions are relatively complex and it is difficult to define a typical pattern. The following show the sequence of search tactics for one case and the case (Table 9) itself.

AccF (to Browser 1 item)→*Searching or Browsing strategy* (in Browser 1 item)→[Open Browser 2]→*AccF* (to Browser 2 item)→[move to Browser 1]→*AccF* (to Browser 1 again)→*Eval and Use or fail to use* (in Browser 1 item)→[move to Browser 2] *AccF* (to Browser 1)→*Eval and Use or not use* (in Browser 2)→[Continuing searching process using multiple web browsers]

In this strategy, it was observed that participants were likely to utilize different types of resources consisting of web search engines, web sites, library catalogs, online databases, *etc.* For example, in one example (S7), to prepare a trip to the Netherlands, a participant used multiple sources, such as a search engine, a commercial Website, a weather information site, a news site, and a travel agency site, *etc.* Also, in another example (S16), a participant utilized different types of sources, including a search engine, a governmental site, a library catalog and an online database, to research about “prehistoric cave arts.”

4.4.2. Item Comparison

Item comparison refers to a strategy that participants checked multiple sources to compare different items in order to select the most appropriate item. The objective of this strategy is to compare similar information from different sources. When comparing two or more items, participants opened two or more web browsers at the same time, and then evaluated these resources one by one. This strategy was observed several times in participants’ achieving online shopping tasks, such as purchasing airline tickets, a digital camera, *etc.* As with *simultaneous multiple resources access* strategy, this strategy shows relatively complicated tactic patterns, because of the dynamic nature of using multiple sources. The following show the sequence of search tactics for one case and the case (Table 10) itself:

AccF (to Browser 1 item)→*Searching or Browsing strategy* (in Browser 1 item)→[Open another browser]→*AccF* (to Browser 2 item)→[back to Browser 1 item]→*AccF* (to Browser 1 again)→*Eval and Use or fail to use* (in Browser 1 item)→[back to Browser 2]→*AccF* (to Browser 2 item)→*Eval and Use or not use* (in Browser 2 item)→[Continuing seeking process using multiple web browsers]

Table 9. Simultaneous multiple resource search strategy.

Web browser 1		Web browser 2	
Tactic	Activity	Tactic	Activity
...
<i>AccF</i>	(newberry.org)		
<i>Creat</i>	[new search query in online catalog of Newberry Library: cook county board of commissioners]		
...	...		
<i>EvalR</i>	[continues to look at search results at the Newberry Library]		
<i>AccF</i>	“I am going to click a link about a research guide” [waits for a PDF file to open from previous link]		
		<i>Lead</i>	“...while I am waiting for that I have a new idea to search for ‘cook county elections’, so I am going to try to use Google”
		<i>AccF</i>	[opens the Google in a new window]
<i>EvalI</i>	[PDF file comes up from the Newberry Library link and now looks at this file] “It covers the time period I am looking ...”		
<i>Use</i>	[takes notes in Notepad]		
<i>Xplor</i>	“there is a link in the Newberry catalog about Chicago Neighborhood Bibliography”		
<i>AccF</i>	[goes to that page]		
<i>EvalI</i>	“I see a listing of different neighborhoods and I am not interested in a specific neighborhood”		
		<i>Creat</i>	[new search query in Google: cook county Illinois election commission]
		<i>EvalR</i>	[looks at results] “it does not like them”
<i>AccF</i>	[goes to the Newberry Library page that is already open]		
<i>Creat</i>	[new search in Newberry Library: (search query) cook county election commission]		
		<i>AccF</i>	“use Google to get their library and search the library catalog”
		<i>Creat</i>	[create a new query of ‘library catalogs’]
		<i>EvalR</i>	[looks at results]
		<i>AccF</i>	[clicks 1st result: University of Illinois – Chicago]
...

Table 10. Item comparison strategy.

Browser 1		Browser 2	
Tactic	Activity	Tactic	Activity
AccF	(Expedia Travel: cheap airfares, hotels...) “flight only, round trip, leaving from Chicago to Seoul, I am going to say I am departing in the next week or so...usually tickets are cheaper during the middle of the week” [enters search criteria]	AccF	[opens new window while waiting for query results; types Google URL]
Creat		Creat	[query: cheap tickets]
		EvalR	“cheapticket.com I have used this one before”
		AccF	(cheapticket.com) “flights city or airport entering O’Hare to Seoul...I am going to use the same dates to get a comparison of the sites ...” [enters search criteria]
		Creat	
		EvalR	“see what I got... found that match your search” ... “oh it says no flights were found that match your search” “change search” [clicks link: Change search; alters query] “I will try Seoul, Korea, Incheon International”
		Mod	
		EvalR	“I have one non-stop flight \$1800 which is a little pricey”
		EvalR	“\$1777 looks like the cheapest I can get...let’s see”
AccF	[backs to Expedia results opens window from task bar]		
EvalR	[search results] “one stop \$1657...they are all kind of expensive but not in comparison to the other ones though...”	AccF	[moves to the search results of cheaptickets.com]
		EvalR	“that’s alright I will just use this pad over here” [writes info. on paper] “...the cheapest ticket was \$1777... this one is Korean Air and the other one”
AccF	[backs to Expedia results opens window from task bar]		
EvalR	“I think Delta, yes Delta... actually it is \$1877 with taxes and fees and that’s Korean Air... Cheap tickets”		
Use	“actually it is \$1877 with taxes and fees and that’s Korean Air... Cheap tickets.” [writes info. on paper]		
...

In this strategy, participants were likely to use resources with similar characteristics. In one example, a participant (S13) who planned to visit Las Vegas used five different travel agency sites, such as Expedia, Travelocity, Priceline, and Orbitz, which all offer discounted flight tickets. In another example (S5), a participant who wanted to purchase a camcorder visited four online shopping sites: Best Buy, Target, Circuit City and Walmart.

4.5. Starting

Getting a good start is half the job. Starting strategies are essential for the successfulness of information searching. The authors investigated how participants started their search tasks by analyzing the initial tactics in each search episode. Based on the analysis of 60 cases, two predominant starting strategies were identified: one is to begin with a search query, and another one is to get started from exploring a known site.

4.5.1. Query Initiation

Query initiation refers to a strategy that participants began their search tasks with creating a query. The log data showed that 88.3% of the cases included at least one search query statement with the first six search tactics. A web search engine is the most frequently utilized source for this type of strategy. The following series presents the typical sequence of tactics and an example (Table 11) of this type of search strategy:

Lead→*AccF*→*Creat*→*EvalR*→*AccF*→*EvalI*

In addition, a variant related to this strategy was observed. In one case, a participant applied a learning tactic (*Lrn*) to get started with learning how to use the functions of Google Map in finding some satellite pictures of Rome (S2). When users begin a search with unfamiliar systems or system features, they might need to learn how to make good use of the system or system features to get started.

The following presents the pattern of a variant of starting with a query initiation strategy:

Lead→*AccF*→*Creat*→*EvalR* →*AccF*→*Lrn*

Table 11. Query initiation strategy.

Tactic	Activity
<i>Lead</i>	“so I am going to search and see if they might have a different growing habit so I am going to search for just right now, butterfly bush and see what I can get...and now I am at Google”
<i>AccF</i>	“types up here www.google.com”
<i>Creat</i>	[query: butterfly bush]
<i>EvalR</i>	[clicks 3rd result: Buddleja - Wikipedia the free encyclopedia] ...
<i>AccF</i>	[clicks to Wikipedia]
<i>EvalI</i>	“All right, this did not give me any info that I did not know...”
...	...

Query initiation strategy was the dominant starting strategy. Participants expressed their reasons for the selection of this strategy: (1) Comprehensive coverage: “I feel that starting off with a broad Google search will lead me to many articles, websites and resources relating to my search topic.” (S3); (2) Ease of Use: “I know from past experiences that Google is fairly easy to use” (S5); (3) Familiarity/past experience: “Keyword search is what I usually use and I am usually successful in my search” (S10); and (4) Efficiency: “I use a search engine to do a quick search to see what’s out there” (S20). After starting with query initiation strategy, participants frequently switched to one of the exploration strategies such as iterative exploration and whole site exploration. This type of transition occurred in about 71.7% of all cases. Query initiation strategies were used to find and access relevant items. At the same time, participants also applied exploration strategies as an alternative approach when they could not find relevant items by using query initiation strategy.

4.5.2. Known-item Initiation

Known-item initiation refers to a strategy in which participants began their search tasks from known sites. Seven of the sixty cases started with this strategy. Using this approach, participants accessed the site that they were familiar with or that was recommended by someone else. About 11.7% of beginning patterns could be categorized into this strategy based on the log data. By applying this strategy, participants directly accessed a specific item by typing the URL. The following present the typical sequence of tactics applied and an example (Table 12) of this type of search strategy:

Lead→AccF→EvalI→Xplor→AccF→...

With regard to the known-item initiation strategy, a variant was also observed. Instead of typing the url of a site, one participant began with the known item from a link saved in an email (S20). Users could start their searches from known websites saved in emails, bookmarks, paper notes, etc. This pattern shows a modification of the typical known-item initiation strategy addressed above:

Lead→AccF (access to email account)→AccF (access to a saved link)→Xplor→AccF→...

Table 12. Known-item initiation strategy.

Tactic	Activity
Lead	“because my topic is very recent and it is business related one of my first choices is cnn.com”
AccF	“starts with this website by typing URL”
Xplor	“I am looking for the mortgage industry with homeowners ... ok I at least found some of the general which I guess pieces of the plan kind of called the mortgage freeze”
EvalI	“so that is good info...”
Use	“...that is pretty much the core of the article”
Xplor	“I am scanning [same webpage] ...”
AccF	[clicks link to an article: Bush subprime plan offers help to 1.2M]
...	...

5. Discussion

A significant contribution of this study lies in identifying search strategies based on the analysis of sequences of search tactics. The authors traced search tactic sequences to discover the strategies applied in the information searching process. Thus, the findings of this study not only discover the types of search strategies, but also show corresponding typical patterns of tactics with variations to account for participants' sequential movements in detail. Eight search strategies in five categories emerged from the sequential data of search tactics.

In Table 13, the authors discuss the objective and the weaknesses of each strategy. More importantly, practical implications for the system design in web environments are also suggested. First, in order to help users quickly evaluate search results (*EvalR*) in iterative result evaluation, well-presented meta-information—including title, author, abstract, and topic—would be imperative, since users determine what to access based on the meta-information provided. Also, considering the loop '*EvalR*→*AccF*→*EvalI*→*Use or not*→*AccB*' is an essential component of this strategy, the efficiency of hub and spoke structure, which was identified in Catledge & Pitkow's [36] findings on search strategies, needs to be enhanced. By showing search results and individual items together in one browser, transitions of *AccF* and *AccB* tactics can be easily reduced. Second, for the *iterative exploration* strategy and the *whole site exploration* strategy, design issues have to focus on how to facilitate *exploration* from one link to another. Well-organized and highlighted navigation structure, menu, external links, and internal links need to be implemented into the IR systems. In addition, systems also need to show users the path and the current location so users can easily know their exploration history. It is also useful for systems to offer related external links to expand the scope of exploration for the *whole site exploration* strategy.

Third, as to the *multiple query reformulation* strategy, the system designers can employ previously suggested features including secondary window usage, query tracking, manipulating multiple queries, query expansion, query feedback and suggestions, and others [35,37]. Providing help on domain, system and information retrieval knowledge is an effective way to reduce query reformulation. Fourth, in order to overcome the complicated pattern of the *simultaneous multiple resource search* strategy, offering shortcut keys, allowing users labeling items, and providing simultaneous display of multiple sources could help users move around different sources and find relevant information easily. Fifth, as for the *item comparison* strategy, showing multiple resources simultaneously on the screen, highlighting key information, and allowing extraction of key information can assist users in comparing items efficiently, in addition to facilitating users moving around different resources. Sixth, the implication for the *query initiation strategy* is closely related to the search function design. Thus, every suggestion concerning search function design could be applicable for this strategy, including advanced search, results display, query error correction, query suggestions, predefined keywords, *etc.* Also, users might also have to learn system functions at beginning of the search process. It is important to design context-sensitive help as well as integrated help pages so users are not confused with or stuck in help pages. Finally, integrating users' personal information systems, such as their emails, bookmarks, and personal folders, into IR systems can support the *known-item initiation* strategy by helping access the items easily and quickly.

Table 13. Implications for system design.

Category	Strategy	Objective	Weakness	System design implication
Search result evaluation	<i>Iterative result evaluation</i>	Efficiently identify as many related items as possible	Too dependent on search results; The problem of hub and spoke structure	- Helping search results evaluation: well presented meta-information, search result display, and display options; - Enhancing the efficiency of hub and spoke structure: presenting search results and related items together to reduce access forward and backward.
	<i>Iterative exploration</i>	Effectively browse different aspects of a topic	Not an efficient method of finding items quickly	- Facilitating exploration from one link to another: well-organized information structure, navigability, and menus; - Showing users their browsing paths and current locations.
Exploration	<i>Whole site exploration</i>	Effectively browse different aspects of a topic within one site to save time and effort	Limited coverage	- Facilitating exploration from one link to another: well-organized information structure, navigability, and menus; - Showing users their browsing paths and current locations; - Offering related external links to expand the scope of exploration.
	<i>Multiple query reformulation</i>	Enhance precision or recall	Too many query reformulations indicate ineffective search; <i>Mod</i> tactic itself requires high cognitive involvement and different types of knowledge Requiring more efforts and skills to deal with different resources at the same time; Complicated tactic patterns	- Helping query reformulation: query tracking, manipulating multiple queries, predefined keywords, query expansion, query feedback and suggestions; - Reducing query reformulations: providing help on domain, system and information retrieval knowledge.
Simultaneous multiple resource access	<i>Simultaneous multiple resource search</i>	Utilize multiple resources simultaneously	Requiring more efforts and skills to deal with different resources at the same time; Complicated tactic patterns	- Facilitating movement among different resources easily: designing shortcut keys, labeling the window, showing multiple sources simultaneously.
	<i>Item comparison</i>	Compare items with common characteristics from multiple sources	Complicated tactic patterns	- Facilitating comparison: showing multiple resources simultaneously on the screen, highlighting key data, and allowing the extraction of key information.
Starting	<i>Query initiation</i>	Effectively find relevant information to get started	Dependent on the initial query; Dependent on the search engine performance	- Aids to query creation: search options such as basic and advanced search, query error correction, query suggestions, predefined keywords, <i>etc.</i> - Facilitating learning system or system features: designing context-sensitive help as well as integrated help pages.
	<i>Known-item initiation</i>	Effectively explore relevant information to get started	Requiring prior knowledge on the source	- integrating users' personal information systems with IR systems.

6. Conclusions

This study has identified eight types of search strategies by analyzing sequences of search tactics applied in the web-based IR process. The findings of the study not only show types of search strategies, but also include the typical patterns of sequential search tactics and variations corresponding to each strategy. Design principles are suggested based on the typical tactic sequences.

This study also has its limitations. Thirty-one participants' 60 search tasks are not enough to generate all the search strategies applied in the web IR process. In addition, although the lab environment makes it possible to record log and verbal protocol data by using Morae software, it does not necessarily represent the search process in real settings. Thus, for better understanding of search strategies, data should be gathered in real settings. The think-aloud protocols did provide insight information in relation to participants' reasons for applying different types of search tactics, but less on the selection of search strategies. For that reason, the authors could not confirm whether the participants intentionally applied all of these search strategies. Participants could be probed for their thoughts behind their search strategies. Also, factors related to the application of different types of search strategies are not discussed in this paper because space limitations.

Next, the authors will examine search strategies generated from diaries collected in real settings. Diary data will be compared with log data to reaffirm or complement the findings of this study. More importantly, future research should extend the investigation of search strategies to users' perceptions of applying these strategies. In addition, more users with real problems in real settings with different search tasks are needed to generalize the results of the study. Finally, factors affecting users' application of different types of search strategies also need to be examined. The investigation and identification of various information search strategies in the information seeking and retrieval process will enable researchers and designers to create better information retrieval systems to facilitate users applying different types of search strategies.

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