Needle in a Hyperstack: Searching Information on the World Wide Web

Rafi Nachmias

Amir Gilad

School of Education, Tel-Aviv University, Israel

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Mailing Address:

Dr. Rafi Nachmias
School of Education
Tel-Aviv University
Tel-Aviv 69978, Israel
Phone: 972-3-6406532 Fax: 972-3-6407752
Email: nachmias@post.tau.ac.il

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Abstract

This study examines the process of information search on the Internet by: (a) assessing participants' success in finding specific information on the Web, (b) identifying the characteristics of the information search process (e.g., search duration, number of steps used), and (c) identifying the search strategies used, and assessing their effectiveness. Subjects were 54 university's graduate students who were asked to accomplish three (relatively simple) search tasks: (1) find a picture of the Mona Lisa, (2) find a complete text of Robinson Crusoe or David Copperfield, and (3) find a recipe of an apple pie which includes a photograph. All search process performed by each participant were recorded and fully logged by tracking software. Findings showed that overall success in searching information was low. About 46% of the search tasks were not accomplished successfully. Only 15% of the students succeed in all three tasks. The search process was long and effortful. Further analysis reveals nine different search strategies used by the students. The distribution of their usage and their effectiveness are presented and discussed.

Introduction

Less than a decade since it become generally accessible, the Word Wide Web has become a prominent source of information for many people worldwide. A recent survey reveals that adult Web users search the Internet more than they engage in any other computer activity except for using e-mail (SRI, 2000). Another survey found that half of Web users spend 70% or more of their time searching online (Berrier, 2000). This is supported by the observation that each day about 250,000,000 Web searches are performed by mean of major search engines (Search Engine Watch, 2001). Web searching for information is not only a popular activity but also an important skill in our information-based society. The skills and abilities required to find information on the Web in everyday life situations (e.g., learning, decision making) have become indispensable (Monereo, Fuentes, & Sanches, 2000).

Finding information on the Internet requires a variety of skills: ability to use Internet tools (e.g., search engines), a knowledge of search techniques (e.g., browsing through an information tree), and the cognitive capacity to organize the search for information into productive plans and the ability to execute their plans (Carroll, 1999). Effective use of Web search tools in itself requires certain skills: ability to apply Boolean logic rules (e.g., and, or), understanding how information is organized, critical thinking that enable effective choices, and knowledge of Internet notations. Other types of knowledge also determine the effectiveness of locating specific information, such as general knowledge concerning the field into which the information search is directed, and certain language capabilities (e.g., spelling). The considerable amount of required abilities suggests that finding information on the Web is a rather complex skill, which people cannot simply be expected to possess.

The need for a systematic study about searching information arises from the discrepancy between two views. The first of those is based on the perception of the Internet as an ultimate source of information for learning and for every-day purposes. This perception assumes that everyone can easily and naturally access specific information on the Web. In the second view, effective information searching, being a complex skill, is far from easily accomplished. This view is supported by current research that reports on the "Web rage" phenomenon. According to this survey, 71% of Internet users get frustrated in the process of searching the Internet for specific information (Roper Strach, 2000).

Clearly, we must improve our understanding of the skills required for information searching on the Web, and of the processes involved. Beyond affecting our behavior as individual Web users, such understanding might affect pedagogical decisions regarding the usage of information in education systems. Therefore, the purpose of this study was to shed light on the process of information search over the Internet by regular users. For our research population we selected 54 university's MA students who were using the Internet quite regularly for a variety of personal and educational purposes. We consider them "typical users" representative of many other Internet users. The aims of the study were:

- To assess participants' success in finding specific information on the Web.
- To identify the characteristics of their search process.
- To identify the search strategies used, and to assess the effectiveness of those strategies.

Background

The growth of the World Wide Web has turned the Internet into a huge repository of information with an estimate of two to ten billions of Web pages, depending on the source. However, efficient access to this information becomes more and more difficult. Obviously, this immense information space becomes virtually worthless unless the information on it can be efficiently located and retrieved. This is why the understanding of information searching processes is a highly relevant research issue.

Today, the estimated number of Internet users worldwide exceeds 300 million. Reports on Web usage conducted in the year 2000 indicate that searching for information is a very frequent activity of these users. For example, half of the adult users (who use the Web for five or more hours per week) spend 70% or more of their time online searching (Berrier, 2000). A second study reports that 57% search for information more often than they engage in any other activity except for using e-mail (SRI, 2000). In a third study, 36% of Internet users reported spending more than two hours per week searching the Web for accurate information (Roper Starch, 2000). A study conducted among high-school students in Israel indicated that over 80% of the Web-using students access Internet for information retrieval (Nachmias, Mioduser, & Shemla, 2000). However, these studies are based on users' self-reports as the main data source, and therefore draw a partial picture of users behavior. They describe usage patterns in general terms leaving detailed search behavior and its efficiency unexplored. Trying to view this picture in more details, this study focuses on users' search strategies, their success and effectiveness according to a step by step log of their operation, rather than their self-reports.

One way to enhance our understanding of search processes is to examine the searchers' behavior, analyzing the abilities and skills required for accomplishing a successful search. This approach was applied long before information and communication technologies were as widespread as they are now (e.g., Mote, 1962). This early research dealt mainly with the efficiency of information retrieval systems as used in libraries and for documentation (e.g., Belkin, 1982; Ellis, 1984, Oddy, 1977; Kuhlthau, 1988, 1993; Robertson, 1977; Stoan, 1984). Several theoretical frameworks of information searching as a complex cognitive skill were created. Allen (1991) presented four types of knowledge affecting the interaction of users with pre-Web information systems: (a) world knowledge – general knowledge that might affect the information searching; (b) system knowledge – the knowledge users have about the system they are using; (c) task knowledge – their ability to carry out a search task; and (d) domain knowledge – the knowledge users have about the topic being searched. Hannafin and Hill (1997) using a broader perspective, identified five types of knowledge necessary for information gathering: metacognitive knowledge or awareness of cognitive processes required for successful searches; perceived orientation or awareness of location within the system; judgment of capability to execute actions; system knowledge, and knowledge of the content being searched. However, only few studies aimed at validating this theoretical frameworks with an empirical results (e.g., Carroll,1999; Hess, 1999). Several of this studies describe and analyze the processes and the outcomes of the search (e.g., Bates 1996a, 1996b; Carroll,1999; Saracevic & Kantor, 1988).

The characteristics and the organization of the information that is being searched are major factors affecting search effectiveness. In early study Mote (1962) reported that field of study and success in searching are correlated. Fields that are well

defined were found to be a lot easier to inquire. Bates (1996c), when examining search in humanities studies, stated that interdisciplinary search is more complicated than, say, a search in sciences. This is due to the broader field of study, the more complex process of cataloging involved, and the more associative pattern of search. These claims suggest that the Word Wide Web as a complex interwoven network of ill-defined information should be a difficult place for locating information. Yet, very little research has been done on search patterns in the WWW. Bates and Kafai (1997) were the first to study information search over the WWW in elementary school. Carroll (1999) studied eight expert searchers patterns of information searching. Monereo et. al, (2000) reported on three pilot studies of different users (beginners and experts) searching for specific information, carried out in Spain. All these researchers recommended further studies of searcher's behavior in the WWW, with larger sample size. Our study, reporting on 54 university student's searching patterns aimed at adding one more peace into the puzzle of searcher's behavior understanding.

Method

Subjects

Participants were 54 MA students at Tel-Aviv University's School of Education, aged 25- 42 years. All owned a personal computer, had an e-mail address and had been using the Internet on a regular basis for at least one year.

Procedure

Subjects received a brief review of search methods on the Internet in a shape of a 45 minutes small-group lecture. They also received a list of commonly used search engines (e.g., Yahoo, Altavista, Excite). Then, they were asked to accomplish three (relatively simple) search tasks: (1) to find a picture of the Mona Lisa, (2) to find a complete text of Robinson Crusoe or David Copperfield, and (3) to find a recipe of an apple pie which includes a photograph. No additional details regarding the tasks were provided (e.g., name of the author of Robinson Crusoe). There was no time limit, neither were participants asked to perform the tasks in a specific order. All search steps performed by each subject were recorded and fully logged by "Surf Spy"- a tracking software embedded in all computer stations used in the study. Recorded information included: time, http address and searching/browsing string, of each step. Finally, a short questionnaire was administrated to collect data on age, gender, and prior experience in using a computer and the Internet.

Results

Success in search tasks

Success was defined as finding a Website that contained the precise information defined in the search task. Partial information was unacceptable (e.g., a recipe for apple pie without a photograph). Figure 1 shows the overall percentage of success among participants: The overall success rate was low, with only eight participants (15%) succeeded in performing all three tasks. Twenty-one participants (39%) accomplished two out of the three search tasks, 22 (40%) accomplished only one out of the three search tasks, and 3 participants (6%) did not succeed in any.

Insert Figure 1 about here

Figure 2 shows the distribution of success within tasks (the numbers inside the bars indicate the number of search tasks). Unsuccessful search attempts are represented by the white part of the bar. The successful searches are presented according to the source of information found: unofficial (gray), and official (dark). An official information source is a reliable source of information such as Websites of universities, known firms, organizations or governments (e.g., the Paris Louver). By unofficial information we refer to personal sites that provide second-hand information (e.g., the personal site of a student who presents “Mona Lisa” as his favorite art piece). Our assumption is that an official site is more desirable search result. The figures show that of the total of 162 search tasks (54 students times 3 tasks), 74 tasks (45.5%) resulted in no success and 88 tasks (54.5%) in success. Unofficial

information was found in 45 tasks (28% of all tasks) and 43 tasks (26.5%) were resulted in official sources.

Insert Figure 2 about here

Search characteristics

Table 1 describes the averages of time (duration in minutes), number of steps carried out for the search tasks and the length of each step (in seconds), both for successful and unsuccessful search tasks (failures). Of the 162 tasks, 16 tasks were not performed at all and therefore they were excluded from the analysis. Three variables are presented: total *search duration* in minutes, overall *number of steps* in the search (e.g., browsing to another URL), and *length of step* calculated as the average time (in seconds) for a single search step.

Table 1 shows large individual differences in task performance. For example, the maximum time a participant spent on a task was almost an hour (56 minutes), as opposed to a minimum of 1-2 minutes; several searches took over one hundred steps, others were concluded within very few steps. We can also notice that on average, successful search tasks took almost half of the time and steps, than unsuccessful ones.

Insert table 1 about here

Use of search strategies

A useful term for analyzing search behavior is “search strategies” adapted from Bates (1979), who borrowed it from the military lexicon. We defined search

strategy as a user plan that consists of a series of actions (steps), aimed at searching information. For example, the implementation of a typical search strategy would be as follows: The searcher browses to a search engine homepage (e.g., Altavista, Lycos) and type "Mona Lisa" in the search dialog box. As a result, a list of matching sites appears on the screen. He browses to the first URL, returns to the list browses to the second URL and so on, until either finding what he looked for or giving up. We called this series of actions - implementation of the search engine keyword search strategy. If the searcher continued to "Yahoo" to browse through its information tree, we would refer to this as changing from one strategy to a new one.

The 5840 search steps observed and recorded in this study, were analyzed and were divided into 378 search strategies (an average of 15.5 steps per strategy). These strategies are of nine different types. Participants' types of search strategies are described in Table 2. They are divided into three major categories: types of strategies that use search engine, browsing strategies, and direct access.

Insert table 2 about here

Table 3 shows the distribution of the different 378 search strategies used by the research participants while performing the 146 tasks (an average of 2.6 strategies per task). Search strategies were also distributed by successful and unsuccessful search tasks. The numbers in parentheses are the percentage of search strategies used amongst the successful, unsuccessful and total number of strategies. It is noticeable that the search engine strategies used almost three times more than browsing strategies. The simplest strategies (e.g. *direct single keyword search; simple directory; direct typing)* were the most frequent strategies used, while the more

complex strategies were seldom used. No significant differences were found within all strategies used between successful and unsuccessful search tasks percentage.

Insert table 3 about here

To examine the efficiency of the search strategies a further analysis was carried out for the last strategy that participants used in a search task. This analysis is summarized in Table 4. Amongst the last strategies we notice that browsing strategies are better than search engine strategies. Significant differences were found in browsing and search engine strategies between successful and unsuccessful search tasks ($\chi^2 = 4.3$, $p<0.05$). Relatively, larger percentage of failures was found among students who used search engine as final strategy as oppose to students that used browsing final strategy.

Insert table 4 about here

Discussion

The results of this study support the claim that Web searching is a nontrivial complex skill. Almost half of the search tasks carried out in this experiment had unsuccessful results. The search processes were long and effortful. Students spent on average, 12 minutes on a task with successful results and gave up after an average of 20 minutes. These findings are similar to those of Carroll (1999) and Holscher & Strube (2000), both reporting on difficulties encountered by the participants of their studies in searching information on the Web. This sheds some light on research results which have described the frustration of most Web users (71%) when searching the Internet for specific information (Roper Strach, 2000). The variability among searches was high. Some searches were completed after less than one minute (with 1-5 steps) but some took almost one hour (with over 100 steps). We suspect that the rapid expansion of the Web, in terms of both new users and more information, will compound this problems.

For many users, access to the Internet produces a sense of "information overload" with thousands of Web links resulting from one search. The specific information that we look for is not always easily located. Often the non-critical searcher gets overwhelmed and distracted by the amount of information, most of which is not really needed and retrieved by inappropriate search strategy. This puts in a question the effectiveness of the Internet as a major source for learning and problem solving. It is also challenges the users to facilitate a mindful and effective habits in consumption of Internet information.

All participants in this study were relatively experienced Internet users. However, their experience in Internet search was narrower than we expected. Their search processes were ineffective, and in nearly half of the tasks, unsuccessful. Most

searchers use trivial and sometimes ineffective strategies (e.g. typing the string of the requested task in the search engine's dialog box). This supports the claim that the skills required for information searching could not be improved by trail and error without an appropriate training. The implication is a huge challenge for the formal education system: The acquisition of information search skills should be added to the formal learning objectives. Appropriate learning materials focusing on effective search strategies should be designed and implemented.

The results of this study indicated that participants tend to switch between two to three strategies during one search. This finding agrees with Bates' (1989) theoretical model about bibliographical search. Bates claims that the search can lead the searcher into different directions, which may even change the subject of the search itself. The interesting phenomenon is that participants tend to change their strategies even when the search task is defined and permanent.

The most common strategy used by the participants of this study was single keyword search using search engine, although this strategy was found inefficient. Bates (1993, 1996 a, b, c) came up with similar results in the Getty project, where scientists in the humanities were observed to mostly use the direct typing strategy. In the course of the Getty project participants learned to use other strategies as well and the use of direct typing strategy decreased as the searching experience increased.

Use of general knowledge and computer convention was found effective among search engine strategies. Looking at the last strategy applied in a search, the success rate of these strategies was double that of the failure rate. These findings are similar to Mote (1962) that found that when general knowledge is being used during a search, the search tends to be more focused and defined and therefore leads to higher success rates.

Browsing strategies were found to be more effective than using search engines. Of the 30 times browsing was used as last strategy 22 (73%) were successful. It may be that the fact that participants used general knowledge while searching a catalog was one of the reasons for this success. Searching through a catalog presumes that the searcher knows the relationships among categories. For example, if a participant found the Louvre Museum through a catalog, it is most likely that she or he was aware that the Mona Lisa is in the Louvre, that the Louvre is a museum in Paris, that Paris is in France, etc. Although the use of browsing strategies was more effective, the participants in this study used other strategies (e.g. search engines) three times more.

A successful search took approximately half of the time and about half of the steps of an unsuccessful search. There was no difference in the length of steps. This may imply that both search task difficulty and search strategy affect the number of steps but not the duration of each step. An important search skill is the ability to reflect on the search process. Observations showed that participants who failed in their search usually remained with one strategy for a large number of steps, i.e., they did not recognize the ineffectiveness of their selected strategy.

The quantitative analysis of participants overall behavior suggests that inadequate application of search strategy is a major source for search difficulties. We think that deeper understanding of this source might be helpful for the solution of this problem. In-depth analysis of individuals' search strategies is a promising research direction. More research is also needed on the questions to what extent and how the use of effective search strategies can be taught.

A major conclusion of this study is that an unprecedented effort should be invested to cope with the challenge of making information search on the Web more

successful. This effort should be invested in three complementary directions. The first of these is the continuous improvement of search tools. Large Internet companies are putting much money into the development of new search tools (e.g. Google, Copernicus), but they are concerning on the improvement of search algorithms and ignore the aspects of users' search strategies and behaviors.

The second direction for further research is designing new ways of mapping the Internet knowledge. Our findings show that using a directory or a theme catalog is a better strategy to find information on the Web. There are two types of such sites: a centralizing catalog which gathers together addresses of other sites (e.g.Yahoo) and educational sites, which usually consist of a knowledge base and links to external materials. Mapping the Internet knowledge is a source for high quality information retrieval. The major problem in their implementation is funding, particularly when they are non-profitable sites developed by educational organizations for their local target population.

The third direction that research and development should face is education for information literacy. The process of information retrieval and usage has to be learned and taught. When the searchers are aware of the search process they can identify "dead ends" and turn points, evaluate the results of the search, and change the direction and strategy of the search when necessary. Users' meta-knowledge and their ability to reflect on the search process should stand at the center of the curriculum. The educational system should lead the transition from information illiteracy to e-literacy. More research that will lead to improve understanding of searchers' behavior is required and this, in turn, will contribute to advance all the above three directions.

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Tables & Figures:

Table 1: Characteristics of Successful and Unsuccessful Search Tasks (N=146 tasks)

	Successful tasks (*N*=88 tasks)			**Unsuccessful tasks (*N*=58 tasks)**		
	Average (SD)	***Maximum***	***Minimum***	***Average (SD)***	***Maximum***	***Minimum***
Total search duration (min.)	12.33 (8.6)	41	1	20.2 (13.2)	56	2
No. of steps	33 (24.7)	111	2	62 (42.6)	164	4
Length of step (sec.)	26 (12)	65	8.5	22 (9.6)	54	4

Table 2: Participants' Search Strategies

Strategy	***Description***	***Example***
Search engine strategies		
Keyword search	Direct typing of the query subject	Typing the words Mona Lisa.
Wide search definition	Searching using a broad query	Searching for art and painting to find the Mona Lisa.
Complex search	Cross searching with more than one keyword	Picture, Mona Lisa, Louvre
Use of general knowledge	Using information that is not mentioned in the search task	Searching for the Mona Lisa mentioning Leonardo Da-Vinci
Computer convention	Using a computer convention	File suffixes (e.g., .gif, .jpeg)
Boolean search	Using Boolean syntax	Louvre and Mona Lisa
Browsing strategies		
Using a directory	Browsing through a directory or a catalogue	Yahoo directory of topics
Accessing a specific portal	Looking for the subject of interest (requires preliminary knowledge)	www.artnews.com
Direct access strategy		
Direct typing	Simply type a URL	www.monalisa.com

Table 3: Strategy use Distributed by Success and Failure

(N=378 strategies)

	Success	**Failure**	**Total**
Search engine strategies			
Direct single Keyword search	57 (27.3%)	60 (35.5%)	117 (31.0%)
Wide search definition	18 (8.6%)	16 (9.5%)	34 (9.0%)
Complex search	27 (12.9%)	27 (16.0%)	54 (14.3%)
Use of general knowledge	39 (18.7%)	17 (10.1%)	56 (14.8%)
Computer Convention	9 (4.3%)	3 (1.8%)	12 (3.2%)
Boolean search	1 (0.5%)	0 (0%)	1 (0.3%)
Total search engines	**151 (72.2%)**	**123 (72.8%)**	**274 (72.5%)**
Browsing strategies			
Using a directory	46 (22.0%)	38 (22.5%)	84 (22.2%)
Accessing a specific portal	5 (2.4%)	6 (3.6%)	11 (2.9%)
Total browsing	**51 (24.4%)**	**44 (26.0%)**	**95 (25.1%)**
Direct access strategy			
Direct typing	7 (3.3%)	2(1.2%)	9 (2.4%)
Total	***209 (100%)***	***169 (100%)***	***378 (100%)***

Table 4: Final Strategy Distributed by Success and Failure (N=146 tasks)

	Success *N*=88		**Failure *N*=58**	
	Frequency	**Percent**	**Frequency**	**Percent**
Search engine strategies				
Direct single keyword search	17	19.3%	24	41.4%
Wide search definition	5	5.7%	3	5.2%
Complex search	15	17.0%	13	22.4%
Use of general knowledge	22	25.0%	8	13.8%
Computer convention	6	6.8%	2	3.4%
Boolean search	0	0%	0	0%
Total search engines	**65**	**73.9%**	**50**	**86.2%**
Browsing strategies				
Using a directory	19	21.6%	6	10.3%
Accessing a specific portal	3	3.4%	2	3.4%
Total browsing	**22**	**25.0%**	**8**	**13.8%**
Direct access strategy				
Direct typing	1	1.1%	0	0%
Total	**88**	**100%**	**58**	**100%**

Figure 1: Percentage of Success Among Participants

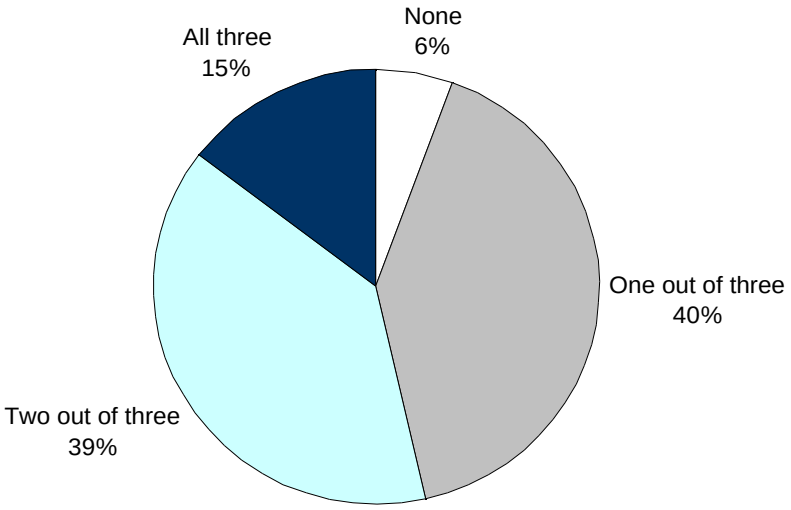

Figure 2: Success According to Task (n=54 participants, performing a total of 162 tasks)