

# QUERY FORMULATION IN WEB INFORMATION SEARCH

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## ABSTRACT

Query formulation is an essential part of successful information retrieval. The challenges in formulating effective queries are emphasized in web information search, because the web is used by a diverse population varying in their levels of expertise. In this paper, the factors affecting query formulation in web information search were studied. The data was collected via a questionnaire (32 participants, each formulated 20 queries). The results of the study suggested that experience in using computers, web, and web search engines affect the query formulation process. Surprisingly, domain expertise did not have an effect on the query formulation. Generally, experienced users formulated longer and more specific queries whereas the queries of users with less experience consisted of fewer and more generic terms. Based on the previous studies concerning query formulation and the results from the questionnaire study, three main factors affecting query formulation are suggested: 1. Media expertise, 2. Domain expertise, and 3. Type of search. These factors should be taken into account when studying and designing information search systems.

## KEYWORDS

Search engines, query formulation, user characteristics.

## 1. INTRODUCTION

In the ever growing World Wide Web (web), search engines are necessary tools for efficient information access. The user population of search engines is extremely heterogeneous consisting of, for example, computer novices and highly-skilled experts, searchers looking for material just for fun and users requiring accurate and efficient search facilities for professional purposes. Currently, most search engines are designed to serve this population on the whole. On usability, however, this produces enormous requirements. To meet the challenges of the diverse user population, search engine designers must thoroughly know the search strategies and possible problems of different user groups.

Information search is a complex process consisting of the four main steps: problem identification, need articulation, query formulation, and results evaluation (Sutcliffe, 1998). This process is affected by environmental (*e.g.*, the database and the search topic), searcher (*e.g.*, online search experience), search process (*e.g.*, commands used), and search outcome variables (*e.g.*, precision and recall) (Fenichel, 1981). This study focuses on the *searcher variables* affecting *query formulation*.

Typically, the studies focusing on information search strategies (or specifically query formulation) have studied professionals searching from bibliographical databases (Fidel 1991a, 1991b, 1991c; Iivonen and Sonnenwald, 1998). These studies provide background when studying query formulation in web searching, but users of web search engines are a very different population and need to be studied independently for complete understanding of their search strategies. Professionals have plenty of training in query formulation whereas the web users usually do not have any training in it. Furthermore, they may not have any special interest in such training. This places the search engines in a demanding position. They should provide relevant results even though the queries are often vague and imprecise descriptions of the user's underlying information need. Furthermore, the lack of organization of the material in the web makes it impossible to formulate efficient queries by considering the contents of the database, indexing terms, or controlled

vocabularies to the same extent as in bibliographic databases. Thus, even professional searchers might need to use different strategies in web information search as compared to searching from bibliographic databases. Although bibliographic information search and information search in the web environment differ significantly, studies focusing on the former are also reviewed. There are currently very few studies on web searching (focusing on query formulation), whereas the literature on traditional search environments is abundant. Furthermore, despite the differences in the search environments, in all text based information retrieval the underlying problem is the same for the user: how to communicate the information need to the computer so that relevant information is retrieved.

Studies of web searchers have usually focused on very large search engine logs files (*e.g.*, Jansen and Pooch, 2001; Jansen et al., 2000; Silverstein et al., 1999; Spink et al., 2000). In these studies, the focus has understandably been on the quantitative data (*e.g.*, number of search terms used), and not the search tasks the users were trying to do, the characteristics of the users who were formulating the queries, the successfulness of their searches, or the concepts that the users used in their queries. In general, the log studies have shown that web searchers use short queries (typically from 1 to 3 terms), seldom use advanced operators, do not regularly iterate their queries, and only go through a couple of result pages per query.

Several studies have found differences in the search behavior of novices and experts. Generally, media (search system, computers, or web) expertise improves performance in search tasks. In query formulation, experts typically use longer queries than novices (Hölscher and Strube, 2000; Fenichel, 1981; Hsieh-Yee, 1993; Sutcliffe et al., 2000). Not only longer queries, the experts usually use more advanced operators than novices (Hölscher and Strube, 2000). The familiarity with the topic of the search task also affects the queries the users formulate: as the users becomes more familiar with the topic, the queries they formulate become longer and more detailed (Vakkari, 2000). Nevertheless, the story is not quite that simple. In another study by Hölscher and Strube (2000), users with *less* topic experience formulated *longer* queries than the users with more experience. The authors assumed that the domain experts knew more appropriate terms and thus, needing fewer of them. However, this assumption was not studied in more detail.

In addition to user characteristics, the type of the search task also affects the search strategies. The tasks can be categorized in two groups, open-ended questions (exploratory searching) and closed questions (fact-finding, question-answering) (Navarro-Prieto et al., 1999; White and Iivonen, 2001). The open vs. closed nature of the task has shown to affect novices and experts differently. In general, the experienced web users are able to change their strategies (*e.g.*, from top-down to bottom-up) flexibly (Navarro-Prieto et al., 1999). How the different types of tasks affect different users in query formulation, is not currently known.

In keyword searching, the more information the searchers provide the system about their underlying information need, the better. Typically, this means that long queries possibly using some advanced operators provide better results than simpler queries. Furthermore, it seems reasonable to expect people to get better in information search with practice (Lazonder et al., 2000; Pirolli and Card, 1999). To conclude, experts in information search, as compared to novices, are expected to formulate better, (*i.e.*, longer and more complex) queries. Generally, the reviewed studies support this idea, although the results are not always consistent with it (Hölscher and Strube, 2000). Thus, we need to study the queries in detail to see the differences in the queries users formulate. In most previous studies, the queries are only described in numerical level and usually, no information is given about the terms chosen, their specificity or generality, etc.

The study by Silverstain et al (1999) showed that almost 64 % of the search sessions in their data set (log data from AltaVista search engine) consisted of only one query. However, the reason for this could not be inferred from the data: It is possible that the users found the information they were looking for immediately or they possibly gave up as soon as they noticed that the search was not successful. Our earlier (unpublished) experiments have also shown similar behavior. In one experiment, 10 users were given 8 search tasks. The participants were given five minutes to find an answer to each task. The analysis of the search behavior showed that there were four users who in at least one unsuccessful task only submitted one query during the five minute time. Instead of trying to improve their query, they chose to go through the same result set for the entire five minute time. In addition to the lack of iteration, users commonly followed their initial choice of the generality of the search terms used. If they started searching with general terms, they usually did not narrow their search even if the search task could not be completed. Although the majority of users seemed to adopt the search terms from the written task descriptions, there were users who generalized even the terms found from the description and used those broad terms in their queries. For example, for a task of finding an answer to the question *How much blood does the human heart pump in one minute?*, one user's initial (and only) query was *human biology*. This query indicates a markedly different approach to finding an answer to

the fact-finding task than a query *heart blood minute* that was formulated by another user. These results clearly emphasize the importance of studying namely the formulation of the initial query. In many cases, the initial query may in fact be the only one the user submits.

Belkin (2000) has nicely illustrated the challenge the users face in text-based information retrieval: “How to guess what words to use for the query that will adequately represent the person’s problem and be the same as those used by the system in its representation.” For some users, this task is presumably easier than for others and our goal is to study the user characteristics affecting the “guesses” they make. Thus, we designed an empirical study to study the factors affecting initial query formulation.

## **2. THE EMPIRICAL STUDY**

### **Questionnaire**

Seventy questionnaires were given or sent to respondents (mainly students and staff of the University of Tampere). The questionnaire consisted of four main parts: the instructions, 20 search tasks (see Appendix), topic familiarity evaluation part, and ten background questions. All participants read the instructions from the questionnaire and filled in the questionnaire independently. The questions were given both in Finnish and in English and the participants could choose the language of their queries freely. In the questionnaire, the participants were asked to formulate the initial queries for the search tasks they were given. Ten of the tasks were fact-finding tasks asking participants to formulate a query for finding an answer to a specific question. Ten tasks were exploratory (open-ended) asking participants to find material related to a given topic. Four tasks (tasks 6, 8, 11, and 14) were taken from the study by White and Iivonen (2001) or slightly modified from their original tasks. The participants were asked to specify which search engine they would use for the given task. After formulating the queries, the participants were asked to evaluate the familiarity of the topics of the tasks on a scale from 1 to 5 (from “I do not know the topic at all” to “I know the topic very well”). Background questions asked participants about their computer and web experience (years of active usage and the frequency of use), search engine experience (search engines actively used, frequency of using search engines, and the participant’s own rating of search skills), and courses taken on information retrieval (if any).

### **Respondents**

32 respondents filled in the questionnaire. All of the respondents were Finnish. The mean age of the respondents was 31 years, ranging from 19 to 61 years. A majority of the respondents had a university level education or were currently university students. All but two respondents used computers daily and on average, they were very experienced computer users (mean 12.2 years, ranging from 2.5 to 33 years). 29 of 32 participants were daily web users and the participants had used the web on average 6.2 years (from 2 to 10 years). The most common search engine used was Google (all but one mentioned using Google), the other search engines mentioned were Altavista, Lycos, Hotbot, Evreka, Dialog, and Micropat. 60% of the participants used search engines daily, 25% used them from 2 to 4 times a week, and 15% less than two times a week. On a scale from one (poor) to five (excellent), the participants evaluated their skills in using web search engines good (average 3.3).

### **Results**

The results are based on the queries formulated by 32 respondents to 20 tasks (640 queries, in total).

#### **Number of Search Terms Used**

The average number of search terms was 3.0 per query. The results showed that there was a positive correlation between web experience (in years) and the average length of the formulated queries,  $r = .52$ ,  $p < .01$  (Figure 1). The correlation between the frequency of using computers and the average number of query terms per search was also statistically significant ( $r = .41$ ,  $p < .05$ ), but since web and computer experience

are closely related (and correlate highly with each other), only the effects of web experience are presented in further analyses.

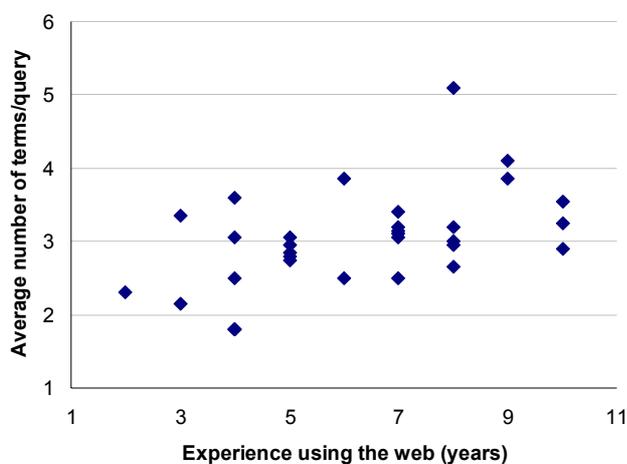


Figure 1: Average number of search terms per query as a function of web experience

## Types of Queries

In addition to the number of search terms, the queries were analyzed in more detail to see how broad vs. narrow the queries were. *Broad query* is defined as a query in which the terms are more general than the terms in the search task (e.g., as in the query *heart structure* for the task *How much blood on average goes through the heart in one minute?*). Additionally, if only half or less than half of the aspects of a multi-aspect task are included in the query, the query is defined as broad. In some queries, aspects are present in the query, but imprecisely. In this analysis, only queries in which the critical aspects are missing completely are included as broad. In practice, the broad queries usually require the user to browse through the results or refine the query in order to find an answer to the question or to improve the relevance of the retrieved documents. The results showed that the frequency of using broad queries was inversely correlated with the frequency of using search engines,  $r = -.54, p < .01$ , with the experience in using the web,  $r = -.59, p < .01$ , and with the frequency of web use,  $r = -.54, p < .01$ .

On the other hand, *precise queries* are targeted at finding relevant documents immediately, without needing to navigate (i.e., the aim is to maximize the relevance of the retrieved documents). For a query to be defined precise in a multi-aspect task, all of the main aspects of the task need to be covered in the query. For example, for the task *How large were the economical losses in the September 11<sup>th</sup> 2001 terrorist attack directed at Pentagon?* the aspects are “economics”, “losses”, “2001 terrorist attack”, and “Pentagon”. If only terrorist attack to Pentagon is present in the query, the query is considered imprecise. Sometimes the aspects are presented in the query incompletely. In this analysis, we require the aspects to be presented completely for the query to be defined precise: For example, the query *September 11 Pentagon losses* was not defined as a precise query, because the losses could be also other losses than economical (the aspect is presented incompletely). The analysis showed that the frequency of using precise queries correlated with the frequency of using the web,  $r = .38, p < .05$ , and with the experience in using the web,  $r = .50, p < .01$ .

## Other Results

The familiarity with the task or the type of task (fact-finding or exploratory) did not correlate significantly with the number of search terms used, the frequency of using advanced operators, or with the frequency of using broad or precise queries. A qualitative analysis of the terms used in the queries showed that only in two tasks, the familiarity with the topic seemed to affect the terms chosen for the query. In the task *Search for a copy of the multinational treaty banning land mines that was signed shortly after Princess Diana’s death, the one that the US and Finland refused to sign*, two participants who evaluated themselves as being familiar or very familiar with the topic, formulated queries *anti-personal mines treaty* and *Ottawa landmine agreement*, respectively (whereas most of the other participants referred to the treaty as “treaty banning land mines”). In

another task (*You are planning to purchase a palmtop computer. Find material that helps you to choose between the brands and models on market by considering their available memory, size, and price*), three participants who were familiar or very familiar with the topic used the term PDA instead of palmtop computer. On the other hand, the familiarity with the topic did not stop participants from choosing general terms to their queries. In the task *How much blood, on average, goes through the heart in one minute?* one participant evaluating herself as familiar with the topic, formulated the query *circulation* (this participant used web a couple of times a week and had about four years of experience using web).

22 of the 32 respondents did not have any formal training in information search. Four respondents had taken a two-hour course in information search organized by the university library, and six users had more training than that (up to having a degree in information sciences). The amount of formal training did not correlate significantly with the number of search terms used, the frequency of using advanced operators, or the frequency of using broad or precise queries.

There was a positive correlation between the frequency of using search engines and the search engine skills as measured by the participants' own evaluation,  $r = .43, p < .05$ . Also the frequency of web use correlated positively with the evaluated search skills,  $r = .50, p < .05$ . The self-evaluated search engine skills did not, however, correlate with any query formulation analyses.

Boolean expressions (OR, AND, NOT, NEAR) and term truncation were rarely used, only on 3.6% and 1.5% of the queries, respectively. Phrase search appeared in 13.9% of the queries. The frequency of using phrase search or term truncation did not correlate significantly with computer, web, or search engine experience. The frequency of using Boolean operators, on the other hand, was inversely correlated with the frequency of using web ( $r = -.86, p < .01$ ) and search engines ( $r = -.47, p < .01$ ). In over 60% of the time, Boolean operators were used unnecessarily (search engine would add the operator automatically). Furthermore, in 17.4% of the cases, there were logical problems in the queries with Boolean operators (e.g., in the query *palmtop computer brand OR handheld computer brand*, parenthesis or quotation marks should have been added for the search engine to interpret the query as the user presumably intended).

### 3. FACTORS AFFECTING QUERY FORMULATION

Based on the previous studies concerning query formulation and the results from the questionnaire study, three main factors affecting query formulation are suggested:

1. Media expertise
  - a. Familiarity with the search environment
  - b. Search engine expertise
  - c. Computer expertise
  - d. Expertise in information retrieval
2. Domain expertise
3. Type of search task

All of the suggested factors were not found to affect the initial query formulation in the present study. Nevertheless, they are expected to affect the query formulation process for the reasons presented below.

Media (web) expertise has earlier been shown to affect search process so that with expertise, the successfulness of search increases (Hölscher & Strube, 2000). However, the effects of expertise on query formulation have not been clear. Our results showed that web (and computer) experience correlate with both the number of search terms used and with the type of query (broad or precise) the user prefers. The more experienced web user the searcher is, the more likely s/he is to use a "straight to information" search style rather than a broader "navigating to information" style. The experts' style can be seen opportunistic: they try to find the information immediately and sometimes they get no results at all (e.g., the query *Baltic sea eutrophication reason environmental effect*, in Finnish, returns 0 hits). Novices, on the other hand, seem to prefer finding at least something to continue the search from and, thus, prefer broader queries (e.g., starting with a query *Baltic sea eutrophication*, returning 300 hits in Finnish). We assume that the more experienced the user becomes with the web, the more the search engines become a tool, rather than something to spend time with. Thus, the users want to search information as efficiently as possible and not just to see if something interesting happens to come by. The web experience also makes the users understand the structure

of the material and the usual style of writing in the web. These skills are a requirement for successful information search (Pollock & Hockley, 1997).

The benefits of having experience using computers are expected to arise from the automatic low-level moves. For example, keyboard and mouse usage are automatic in experts whereas for novices, they require cognitive resources. Automatic low-level moves leave more resources to the primary task of searching for information. Additionally, computer experience is expected to have some implicit effects on information retrieval. Computer illiterate people are often uneasy when using computers. They fear of making mistakes and breaking down the computer. After using computers for a longer time, people inevitably learn that in order to use computers, they need to try things without clearly understanding why and how everything happens. Few people understand how search engines really work, but they can still use them well.

Experts in information retrieval in a broader sense are expected to understand the possible pitfalls in text-based information search. Thus, they may be better in thinking about the search task conceptually, make more advanced queries based on conceptual task analysis, and use techniques for broadening or narrowing their queries as needed. By understanding different indexing and relevance sorting mechanisms (*e.g.*, whether the words are indexed in basic or inflected forms, whether there are ways of weighing some search terms higher in the relevance ranking), they might be more successful in formulating effective queries.

Domain expertise presumably helps people in query formulation by giving them a possibility to use either more terms in their queries (synonyms), or possibly fewer, but more accurate terms. Thus, domain expertise is not directly expected to lead to longer queries, but the quality of the selected terms is expected to be high.

We divide search tasks to three broad categories, *fact-finding*, *exploratory*, and *comprehensive* search tasks. In fact-finding, the source of information is not a key issue. Naturally, if the searcher wishes to find a correct answer to the question, some sources of information are better than others. However, in experimental settings the search tasks are not personally important and the credibility of the source is not likely to be an important factor. In fact-finding tasks, the precision<sup>1</sup> of the result set is a key issue for efficient search. Thus, a good query offers the user a precise set of results, the size of the result set is not important. High precision can be achieved by using precise terms or phrases in the query, and typically, by formulating a query consisting of several terms. On the other hand, in *exploratory* search tasks, the searcher's aim is to obtain a general idea of the search topic or possibly to retrieve a couple of documents as an example. In these tasks, high precision of the result set is not necessarily the most important thing, nor is high level of recall. Instead, the searcher may find relevant (topic-related) documents with simple queries and possibly by using the search engine's result only as a starting point from where the relevant documents can be found by following hyperlinks. Thirdly, when the task is to find as many documents as possible on a given topic (*comprehensive search task*), the recall should be as high as possible for the search to be successful. In search tasks where the recall needs to be high, the level of precision inevitably suffers. High recall requires the user to use broader terms, term truncation, or other methods for maximizing the recall. Particularly in the web, to have the level of precision and the number of results retrieved in an acceptable level, the query must still have the most important aspects of the search topic.

For users with different levels of experience in using computers, web, and web search engines, different types of tasks are not equally challenging. In exploratory tasks, the broad style of searching (a style that less experienced seem to prefer) is presumably a good strategy. With narrow queries, important aspects of the task may be forgotten, whereas a broad start will make it easy for the user to collect new query terms from the retrieved documents. In fact-finding, however, submitting a broad query is like tossing a coin, you may win (find the appropriate document immediately), but you are as likely to end up with having a pile of useless documents and still not having an answer to the question. In fact-finding, it is good to know the strategies for narrowing the search and by that, getting rid of the irrelevant documents. Here, web, computer, topic, and search engine expertise are all supposedly helpful. In comprehensive search, the process of search becomes the most important key to success. In order to find all (or more realistically, some) important information on a topic, the searcher must make several successive queries or formulate one comprehensive query. In order to formulate a comprehensive query, the user must know how to use advanced operators (*e.g.*, Boolean OR and AND). For this task, general understanding of information retrieval and logic is beneficial.

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<sup>1</sup> For measuring the successfulness of information search, two measures, *recall* and *precision*, are typically used. Recall measures the ratio of the relevant documents found and the total number of relevant documents in the database, whereas precision tells the number of relevant documents retrieved divided by the total number of retrieved documents.

## 4. DISCUSSION

This paper predicts that the levels of experience in using web, search engines, and computers all make a difference in the query formulation. In addition to that, also the type of the search task, the knowledge of information retrieval in general, and the familiarity with the topic of the search are expected to make the query formulation either easier or even more challenging. When studying information search with user studies, these factors need to be taken into account as possible confounding variables in the test design. Furthermore, these results suggest that in order to help users in information search, it is necessary to assist them already in the query formulation phase. The help can be provided, for example, by suggesting specific query terms to the users on the basis of their initial queries.

A surprising result was that people using web less frequently used more Boolean operators in their queries than frequent web users (compare with the results from Hölscher and Strube, 2000). However, when the queries were analyzed in more detailed, it was noticed that most of the time, Boolean operators were used unnecessarily (*e.g.*, the search engine automatically added AND operators). Importantly, the logical problems with the Boolean queries were also relatively common (in over 17% of the cases in which Boolean operators were used). This result suggests that people with less experience may want to formulate sophisticated queries, but have considerable difficulties in formulating them correctly. This should be taken into account when designing search interfaces by offering support for query formulation and interpretation. It is likely that more experienced users have already learned when the Boolean operators are needed and use them only when necessary (they strive for efficient search performance and thus, minimize unnecessary complexity).

Our study did not reveal all the effects that are predicted to affect query formulation. This is supposedly due to some methodological issues. Had the search tasks been chosen differently, the familiarity with the domain of the task might have had an effect on the queries the participants formulated. Now the task descriptions were so specific that the query terms could be found from them. On the other hand, it is possible that the domain knowledge is not that important in the initial query, but becomes more important in the later query formulations, if it turns out that the simple terms are not enough. In this study, the population filling in the questionnaire was quite homogenous. Although the respondents had different educational backgrounds, they all were experienced computer users. In fact, in most of the previous studies, people with more than five years of computer and web experience would immediately be called experts. However, differences were found between the respondents of different experience levels even with this sample. We believe that the differences between real novices and experts are most likely even more pronounced than the ones found here.

Future studies need to study query formulation with a more heterogeneous population and also with users making the queries in a real information search setting using real search engines. It is conceivable that some aspects of the query formulation are hidden with an off-line pen-and-paper study.

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## APPENDIX: SEARCH TASKS

1. Find material in which Kaj-Erik Relander comments the accusations presented in the Sonera book.
2. Find information about different treatments for children's otitis and the benefits and drawbacks of them.
3. Which movies has Kati Outinen acted in?
4. Find news articles that tell about the demonstrations against the Iraq war.
5. Find a web page in which the names for the four lobes of the human cortex are given and examples of the processes that different lobes participate in.
6. Find information about the economical situation of the Amazon Books during its history.
7. In which year was the Finlandia award given for the first time?
8. Who are the current members of NATO, the North Atlantic Treaty Organization?
9. How large were the economical losses in the September 11<sup>th</sup> 2001 terrorist attack directed at Pentagon?
10. Search for information about the eutrophication of the Baltic Sea, the causes of it, and its environmental effects.
11. Search for a copy of the multinational treaty banning land mines that was signed shortly after Princess Diana's death, the one that the US and Finland refused to sign.
12. How much blood, on average, goes through the heart in one minute?
13. You are planning to purchase a palmtop computer. Find material that helps you to choose between the brands and models on market by considering their available memory, size, and price.
14. What is the World Health Organization doing to stop river blindness in Africa?
15. Which were the most profitable movies of the Miramax film corporation in 2002?
16. Which virus causes the pneumonia spreading in Eastern-Asia?
17. Find information about what needs to be done to the grass in the spring in order to guarantee its growth.
18. Kari Kärkkäinen is a Member of Parliament. To which party does he belong?
19. Find studies that deal with the global warming and the reasons for it.
20. How old is the CEO of Microsoft, Bill Gates?