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www.emeraldinsight.com/0022-0418.htm

Received 8 May 2006
Revised 13 August 2006
Accepted 15 August 2006

Search persistence and failure on the web: a "bounded rationality" and "satisficing" analysis

Yazdan Mansourian
Department of Educational Technology, Faculty of Psychology and Education, Tarbiat Moallem University, Tehran, Iran, and

Nigel Ford
Department of Information Studies, University of Sheffield, Sheffield, UK

Abstract

Purpose – This paper aims to examine our current knowledge of how searchers perceive and react to the possibility of missing potentially important information whilst searching the web is limited. The study reported here seeks to investigate such perceptions and reactions, and to explore the extent to which Simon's "bounded rationality" theory is useful in illuminating these issues.

Design/methodology/approach – Totally 37 academic staff, research staff and research students in three university departments were interviewed about their web searching. The open-ended, semi-structured interviews were inductively analysed. Emergence of the concept of "good enough" searching prompted a further analysis to explore the extent to which the data could be interpreted in terms of Simon's concepts of "bounded rationality" and "satisficing".

Findings – The results indicate that the risk of missing potentially important information was a matter of concern to the interviewees. Their estimations of the likely extent and importance of missed information affected decisions by individuals as to when to stop searching – decisions based on very different criteria, which map well onto Simon's concepts. On the basis of the interview data, the authors propose tentative categorizations of perceptions of the risk of missing information including "inconsequential" "tolerable" "damaging" and "disastrous" and search strategies including "perfunctory" "minimalist" "nervous" and "extensive". It is concluded that there is at least a *prima facie* case for bounded rationality and satisficing being considered as potentially useful concepts in our quest better to understand aspects of human information behaviour.

Research limitations/implications – Although the findings are based on a relatively small sample and an exploratory qualitative analysis, it is argued that the study raises a number of interesting questions, and has implications for both the development of theory and practice in the areas of web searching and information literacy.

Originality/value – The paper focuses on an aspect of web searching which has not to date been well explored. Whilst research has done much to illuminate searchers' perceptions of what they find on the web, we know relatively little of their perceptions of, and reactions to information that they fail to find. The study reported here provides some tentative models, based on empirical evidence, of these phenomena.

Keywords Information research, Worldwide web, Information retrieval

Paper type Research paper

Journal of Documentation
Vol. 63 No. 5, 2007
pp. 680-701
© Emerald Group Publishing Limited
0022-0418
DOI 10.1108/00220410710827754

The authors would like to express their sincere appreciation to the interviewees who generously gave up their valuable time to participate in this study.

Introduction

Because of the immensity and diversity of information resources on the world wide web (hereafter the web) the possibility of missing relevant information while web searching can be high. This possibility is much greater on the web compared to classic information retrieval systems. "Missed" information in this paper refers to information items which have been or could be retrieved by the search system but of which, for whatever reason, the user fails to be made aware. Searchers thus miss information which may have been helpful to them. Millions of people search the web daily, and it is not clear: how successful they are in conducting effective searches; how much information they may be missing; how important such missed information may have been to them; and how concerned they are about the possibility that they may be missing information.

Deciding when to terminate a search can be problematic, since it is not always easy to know when what has been retrieved represents the best possible search outcome in relation to a particular need. The possibility and extent of missing information are likely to vary according to different search circumstances, and it is difficult to estimate for any particular search session how much relevant information might have been retrieved, and how useful it might have proved, had searching been performed differently or for a different duration. They are also likely to vary according to individuals' skills in executing efficient searches. It is possible that less experienced users with lower levels of searching competence might miss more information.

It is likely that user perceptions of the search effort required, the anticipated benefits of such effort, and the likelihood and perceived impact of missing information, in relation to different kinds of information need are important determiners of search behaviour. They are also likely to affect the amount of effort people are likely to be prepared to commit – and see as necessary – in relation to undergoing search training. A better understanding of such issues is arguably important if we are to improve search training and search engine features such as help systems. Such knowledge is also likely to be an important prerequisite baseline for a better understanding of the relationship between both subjective and more objective aspects of search effort and outcome. However, our current knowledge of these issues is still limited. The study reported here seeks to illuminate such perceptions.

Background

Since, Catledge and Pitkow's (1995) early study of web searching, many investigations have been conducted to enhance our understanding of the interaction between searchers, web-based resources and in particular web-based search facilities (Spink *et al.* 1998, 2001; Hsieh-Yee, 1998; Choo *et al.* 2000; Lazonder *et al.* 2000; Wang *et al.*, 2000; Spink, 2002; Ford *et al.* 2002, 2003, 2005a, b). A number of review publications can provide the reader with a general picture of the main trends and issues in this area (Hsieh-Yee, 2001; Jansen and Pooch, 2001; Spink, 2003; Martzoukou, 2004; Spink and Jansen, 2004).

Researchers have generally been interested in learning how people surf the huge ocean of information, and how they satisfy their information needs through web searching. Although research into web searching covers many aspects, a review of the literature suggests that researchers in the area have mainly focused on what users find and how they employ search facilities to satisfy their information needs. They have

paid less attention to how web searchers perceive, and react to the possibility that their searches may have missed potentially useful information.

The notion of what constitutes "missed" information is interwoven with that of relevance – a concept that has received considerable attention in the past. Indeed, to explore how successful a search is we need some assessment of how relevant both retrieved and missed information are deemed to be from the searcher's point of view. However, this is problematic not only because of the obvious difficulties and vagaries surrounding searchers' perception of what has not been retrieved, but also because of the subjective, cognitive, situational, multidimensional and dynamic nature of relevance itself (Choo *et al.*, 2000).

This paper explores the utility of the concepts "bounded rationality" and "satisficing" in illuminating searchers' perceptions of missed information. These concepts were originally developed by Simon (1955, 1956). Bounded rationality theory basically suggests that in real situations people are only "rational enough" or "partly rational" rather than being "absolutely rational". According to Gigerenzer and Goldstein (1996, p. 651):

> Satisficing, a blend of sufficing and satisfying, is a word of Scottish origin, which Simon uses to characterize algorithms that successfully deal with conditions of limited time, knowledge, or computational capacities.

Agosto (2002, p. 16), citing Simon (1955, 1956) notes that:

> Simon . . . rejected the idea of optimal choice, proposing the theory of bounded rationality. He argued that due to time constraints and cognitive limitations, it is not possible for humans to consider all existing decision outcomes and then make fully reasoned, purely rational, choices. He suggested that humans operate rationally within practical boundaries or within the limits of bounded rationality.

In fact, the theory of bounded rationality illustrates how different constraining factors can influence people's decision making in real situations. As Selten (2001, p. 14) reported:

> Full rationality requires unlimited cognitive capabilities. Fully rational man is a mythical hero who knows the solutions of all mathematical problems and can immediately perform all computations, regardless of how difficult they are. Human beings are very different. Their cognitive capabilities are quite limited. For this reason alone the decision behaviour of human beings cannot conform to the ideal of full rationality.

The benefits of bounded rationality comparing other alternative theories have been discussed in the previous studies. For example, Zach (2005) concluded that web users are mainly "satisficers" rather than "maximizers". Zach (2005, p. 25) reports that:

> Cooper's (1976) utility theory posits that users stop looking for new material at the point at which the effort of the new search outweighs the benefit of the new information. However, . . . it is difficult to predict the benefit of the new information without actually having it. The utility approach is similar to a traditional cost/benefit or cost/effectiveness analysis; evaluating the information-seeking process in these terms is difficult, since it is hard to establish objective values or weights for the variables involved.

Indeed, Simon's bounded rationality and Zipf's (1949) principle of least effort have much in common in that they deal with similar aspects of human behavior relating to people's attempts to minimize the amount of effort they expend. Zipf's law shows that

if there are different routes to achieve a goal, people tend to select the easiest option involving the least effort. However, it is important to note that this is not entirely straightforward in that people may not necessarily take the immediate least-effort choice if they anticipate that greater effort now may in fact result in less overall effort in the long-term.

Bounded rationality and satisficing were originally developed in the context of economics and organizational behaviour, and have been successfully employed in other areas (Gigerenzer and Selten, 2001). However, as Agosto (2002) pointed out that they have received little attention in the library and information science (LIS). Nevertheless, reviewing the literature suggests that there are more citations to this theory in the recent LIS research. For example, three years after publication of Agosto's (2002) paper Griffiths and Brophy (2005, p. 551) reported that:

> . . . users do not always have to concern themselves with exhaustive searches encompassing many resources in order to be satisfied that they have the best information they can get. Indeed, this may be said to be the age of information satisfying-when something is good enough for the purpose rather than seeking to optimize the result (Simon, 1957).

There are other examples of previous studies about how and when people stop searching which are in some ways similar to bounded rationality theory but in different terminologies. For instance, Kraft and Lee (1979) studied users' stopping behavior and identified three types of "stopping rules" including:

(1) the satiation rule;

(2) the disgust rule; and

(3) the combination rule.

Regarding the satiation rule the user stops searching when s/he feels satisfied with the amount of retrieved information. In the second rule, the disgust rule, the user terminates a search when s/he feels overwhelmed because of dealing with too many irrelevant documents. Finally, the combination rule implies when the user decide to stop his/her search either because of satisfaction with the identified resources or when s/he becomes disgusted as a result of scanning too many documents.

Research questions and methodology

Research questions

The study reported here forms, part of a wider study designed as an inductive qualitative investigation of academics' perceptions of search success and failure, with particular reference to the "invisible web" (Mansourian and Ford, 2006a) and users' perceptions of success and failure in web searching (Mansourian and Ford, 2006b). Inductive analysis of transcripts of a series of semi-structured interviews suggested differences in the criteria that searchers used in their decision-making relating to when to terminate their searches. As can be seen from the interview schedule reproduced in Appendix, none of the interview questions focused specifically on this issue, and these perceptions emerged unanticipated from the interviews.

A central element of bounded rationality theory is "satisficing" or the stopping of decision-making when a "good enough" as opposed to optimal, solution is found. In view of the apparent relevance of these concepts to the issue of when to stop searching, it was decided to explore the research question:

RQ1. To what extent are the concepts "bounded rationality" and "satisficing" useful in interpreting interviewees' perceptions of their searching-related decision-making?

Methodology

The particular analysis reported here was of data already collected as part of a wider qualitative inductive study of academic searchers' perceptions of web searching. These data consisted of interview transcripts from a series of 37 in-depth semi-structured interviews, as described below.

Sample

The sample consisted of 37 academic staff, research staff and research students from the departments of Animal and Plant Sciences, Biomedical Science and Molecular Biology and Biotechnology at the University of Sheffield. All members of the research population of the three departments were contacted individually by letter. Thirty seven agreed to participate, and all were interviewed. This sample represented 9.5 per cent of the total 389 members of academic and research staff and research students in the biology community at the University of Sheffield.

Data collection

Interviews were held in the offices of the participants and recorded digitally. The average duration of the interviews was 45 minutes, ranging from a maximum of 1 hour and 14 minutes to a minimum of 28 minutes. Critical incident technique (CIT) was adopted as a means of facilitating data collection. This study used Flanagan's version of CIT (Flanagan, 1954). In CIT, participants are asked to remember and describe a recent and important incident related to the subject under investigation – which in this research was web search scenarios. CIT was used to provide the researcher with a detailed picture, in their own words, of users' interaction with the web. This technique worked well since without exception interviewees were able to remember at least one recent search in detail. Interviews were transcribed, each interviewee being sent his/her transcript to enable confirmation of its accuracy, and to provide an opportunity for possible changes and further comments.

Data analysis

The interview transcripts were analysed in order to explore the extent to which the data could be illuminated by the concepts of bounded rationality and satisficing. These concepts were studied in relation to information science in a paper by Agosto (2002) in which she explored young people's web-based decision-making. She developed a framework for coding interview transcripts based on Simon's theory, and was able to map interview transcripts onto all main elements of the theory. This framework was developed to code interview data from ninth- and tenth-grade schoolchildren concerning their web-based decision-making in relation to evaluating websites, as opposed to searching. It was decided to utilize Agosto's coding framework to assess the extent to which elements of bounded rationality theory were present in – and thus may illuminate – the current data. However, Agosto's additional "personal preference" codes have not been included in this study since they relate to web site evaluation and are arguably not relevant to web searching. The framework is shown in Figure 1.

Bounded Rationality	Time constraints ▪ Imposed ▪ Self-generated Information overload ▪ Textual overload ▪ Outcome overload Physical constraints ▪ Discomfort ▪ Exertion
Satisficing	Reduction ▪ Known sites ▪ Synopsis ▪ Categorization Termination ▪ Acceptance ▪ Discomfort ▪ Boredom ▪ Time limits ▪ Snowballing

Figure 1. Agosto's "bounded rationality" and "satisficing" coding scheme

Findings

It was possible to map interview data onto all Agosto's bounded rationality and satificing categories. The sections below present quotations from the interview transcripts illustrative of each of these categories.

Bounded rationality

Time constraints. The data revealed that shortage of time is one of the most frequently mentioned reasons for stopping searching. There are two types of time constraints: imposed and self-generated.

Imposed. Imposed time constraints happen as a result of external factors that are out of the searcher's control and limit the amount of the time that s/he can afford to spend on the search.

> It is a crucial point these days. There aren't enough hours in a day anyway. How much time can you afford to spend searching the web? You have to limit it.

> There are a lot of things to do, always a lot of other things to do, I mean in the lab, down in the growth rooms. So, I mean there's always something to do. So, I limit probably more than most people how much time I would spend searching.

Self-generated. Self-generated time limitations may result from searchers simply preferring not to spend time searching – as opposed to any specific limitation on the time they have available so to do if they wished:

> I suppose I don't play with the web a lot. I don't experiment with it . . . I don't want to waste time by doing it.

> For most things I am looking for I find them in the first page and I am not that interested in surfing the Internet for pleasure. I don't always look up holidays and things. I booked a holiday about a month ago, but I just looked up one particular site and booked it immediately. I didn't go through the other ones. I went through a little bit, but not that much. I mean some people I know spend a lot of time, but I don't.

Information overload. The enormous volume of information on the web can cause difficulties for searchers. The participants in this study frequently indicated that they felt uncomfortable with having to deal with such huge amounts of information:

> It is obvious that I miss lots . . . because although I am saying there is not a huge amount [because her research topic was so specific] there are still enough to keep you busy for half a day every day. There is enough information and just because of a sheer volume of information you know you are going to miss most of it.

Information overload may be differentiated into textual and outcome overload. Textual overload is defined here as an inability or unwillingness to read information that one has identified as potentially relevant were it not for the sheer volume of it. Outcome overload represents a stage before textual overload, in that it is an inability or unwillingness to process large hit lists in order to establish what is and is not potentially relevant.

Textual overload. Although the web offers information in many different formats, still the major portion is in the form of textual materials. Sometimes web users feel overwhelmed by the substantial amount of textual resources that are potentially relevant to their needs:

> I would probably do a journal search rather than using the web-based resources because I would expect spending a lot of time going through thousands of hits . . . in fact I don't really want to spend as much time that I need to refine my searches on the web circumstances.

> I am sure that I miss things every time, but that doesn't necessarily mean I fail. As I said if you are looking for specific piece of information then you get that, that's fine. A case in point would be looking for recent information on a particular bit of a cell, for example, we call it "cytoskeleton" and I know if I try to search for some recent general information on the "cytoskeleton" I can hit two or three reviews. I will not hit everything but I haven't got time to read everything anyway. So, as long as what I am getting is up-to-date and reliable . . . and that is a success unless you looking for very specific items of information but even then you are unlikely ever to get everything that is available and I don't think it is important you do get everything available.

Outcome overload. The volume of retrieved items can often prevent searchers from scanning them all. Indeed, a number of studies have suggested that web users tend to look only at the first or first two pages of results (Spink, 2003).

> If I go and will put in say "Arabidopsis" then I'll get thirty billions hits whereas I am just not being specific but that is just the way that my brain works.

> I don't have the patience to narrow it down and still you have three billions hits and I'm thinking "NO, NO, NO," it is just too much . . . and sometimes it can be overwhelming really.

> Frequently so much information comes up and it takes too long to go through it all. So you are not able to come to a satisfactory conclusion. You actually just take the first or a few that they are on offer.

Physical constraints

Discomfort. Using computers can be tiring, particularly for those for whom such use is not a leisure activity (e.g. playing computer games). Resultant discomfort may be physical and/or mental, and may become a factor in decisions when to stop searching:

> Well, it [web searching] is necessary, but I do not feel particularly comfortable . . . I do not like it . . . because I spend so much time on screen already, I do it when it is necessary but I am not enjoying it particularly.

> To him it is a hobby whereas to me it is a part of the job. So, the way that he approaches that is going to be different. You know computing is his big hobby . . . anything to do with this machine . . . to him is like a pleasure. So, he learns the search as part of his learning process. But I just use that to get my stuff; to me it is a chore, a task, a job that has to be done. So, it is not so pleasurable.

Exertion. The level of required effort may also be an influential factor. Although usually the web provides end-users with quick and easy access to information, sometimes web searching requires a considerable amount of effort. The following quote is an example of this issue:

> Sometimes I will lose my patience and not continue. If I am not getting there in so many stages then I'll give up. So, that is a complete unsuccessful search . . . I mean there are some sites that I avoid because there are too many links within a site which really annoys me . . . too many links jut to get where you want to get. If you bookmark everything you want to then you never get through your bookmark list. So, I don't bookmark everything. So, sites like that have too many links to get to . . . it would take thirty clicks, you know, something crazy and that puts me off . . . I think probably if you put in a search and you get to a site that looks promising, say a chemistry site, and I am looking for a particular compound but there is too many links to go . . . so, I can probably waste a lot of time saying "NO!" I want a better site.

However, it is worth noting that conversely, the same factor may militate in favour of web searching as opposed to other forms of information seeking:

> In general, I find it very convenient. It is good to have information accessible from my office because although the library isn't very far away, it is easer to have five minutes to go on the web than just walk to the library.

Satisficing

It became clear from the data analysis that it was extremely common for the interviewees to bring their searches to a halt before they felt they had found all relevant information. In particular, the concept of "compromised" as opposed to "ideal" searching, i.e. stopping a search when it was felt to be "good enough" or further searching was deemed impractical for various reasons – was a common reason for bringing searches to a halt:

> If there are thousand documents and I have found five and it allows me to do my job, I don't really mind that I haven't read 995. As long as I have done the job and make the argument that needs to be made, then it is okay. I just move on.

In terms of satisficing strategies, it was possible to map the data onto all the categories identified by Agosto, as illustrated in the sections below.

Reduction. One satisficing strategy is to reduce the search task, for example by restricting searching to known sites, making use of synopses or using categorized sites.

Known sites. Some of the participants reported they usually have a specific set of frequently visited web sites which they have found useful to satisfy their information needs. They keep a record of their frequently used web sites in different forms. The following three quotes are examples of known sites:

> I use a limited number of sites for genome sequences. For journals, publications, [and] for electronic journals, I use a very limited number of sites. We are talking about three or four sites.

> I go to news pages and catch up on news, but I don't search for them because they are on my favourites.

> I looked for the book on the Amazon website. I had that bookmarked anyway. Amazon is a quite regular source of information of books for here and for home. So, that was a nice and easy one.

One of the participants declared that having a list of bookmarked websites helps her to carry out better defined searches:

> I have sort of journals and specialized sets and I have bookmarked so and so and also websites that are specialized in plant science. So, I can go to them which narrow down my search . . . and I use that.

Synopsis. One of the strategies that help users gain more satisfactory results through web searching is use of synopsis in various ways. For example, one of the interviewees mentioned that he uses a web-based selective dissemination of information (SDI) system which helps him reduce the amount of accessible information:

> I have signed up to . . . PubCrawler [http://pubcrawler.gen.tcd.ie/] . . . and all it does is search for new publications with my keywords . . . I have about 10 or 15 keywords and it just pulls up all the new papers every week . . . this service is very useful because there is such huge amount of literature. You can't look through the titles in all the journals every time they come out. I mean I get e-mailed the contents list of about three or four journals but not of 30 journals and of course, the information, the papers that I would want could be published in one of thirty journals. So, this is the only way that I can do it. Because . . . it prompts me to actually look through this list each week and then I just download directly into EndNote. And if there are any interesting ones, I just print them out straightaway.

One of the participants used current contents weekly report as a synopsis of newly published materials. He has been using it for a long time even before the emergence of the web. Although he does use the web-based service, he believed the printed format of this service is faster:

> There was a big index book called Index Medicus and Current Contents. They were coming every week. So, instead of using computers it was manual and thinking a little bit about that it was faster to do it manually... I could look at one issue of Current Contents in about eight to

> ten minutes. Now I have to switch on the computer, log into Current Contents, type the keywords, find information. So, manually was faster.

Categorization. Similar to the notion of known sites is that of categorized sites, these two being differentiated in Agosto's coding scheme. The quote below is an example of categorization method which has been reported by one of the participants:

> As long as you know which sites to use I think it is quite easy to find stuff on the Internet. I mean if you want to find literature for example then you would go to PubMed or Medline or something like that and people tell you where you should go for the literature or if you want to look for DNA sequence then might say to you go to the NCBI web site or something.

Another participant reported a more detailed categorization of different kinds of searches that she does. She firstly categorized her searches into two main categories of work-related and everyday life searches. Furthermore, she classified work-related searches into different subcategories (e.g. scientific papers, experimental methods, and purchasing laboratory equipment). She also divided everyday life searches into several subcategories (e.g. house hunting, travel information, and shopping):

> In the work environment online journals, general protocols, information about where different labs are and who works in them and maybe facilities and services available for experiment. For private reasons, I did use it [the web] quite a lot when I was buying a house searching estate agents' pages for properties. I use it for weather forecasts, sometimes TV guides or cinema guides . . . Sometimes I go to the websites of shops like B&Q and something like that. Sometimes I use Scoot [www.scoot.co.uk/] . . . it lists the local businesses and you can select . . . like a business finder which is quite useful or yell.com [www.yell.com] which is yellow pages online. The search engine that I usually use is Google.

Termination. There are a number of what Simon termed "stop rules" which in the present context enable people to decide when to terminate a search. The following quote shows an example of the participant's view about this issue:

> If you think about it too much you waste time . . . that is bad if you get frustrated because you can't find something. Sometimes it becomes like a challenge, doesn't it? You have to try to look for it and you think the system is defeating you, you know, and you get angry at it. So, that is probably when I say that is enough. Stop it. I am not going to look at it anymore.

Termination has five aspects including acceptance, discomfort, boredom, time limits and snowballing. They are explained and illustrated below.

Acceptance. Searches may stop as soon as they find what they consider to be an "acceptable" search result. The following excerpts from the data are three examples for this category:

> I think it is just part of the life. It is part of the research searching for things and it doesn't always work. I mean it's disappointing – yeah – if I've spent half an hour or more trying to find something. Yes, you do get disappointed and think 'oh yeah – should I have been doing something else or am I wasting my time?' You know you've got to accept it. You've got to do these things sometimes. I get lucky if it works and I have more successes than failure. So, I generally accept that. Occasionally it just doesn't work . . . yeah, I accept it. Life isn't always going to work!

> Often you just keep looking until you've found as much as you want or as much as you need. But I know that often there're more things out there. But I stop when I find what I want.

> I think it is quite likely [to miss information] and we have to accept this. If you look at specific thing you can find it but there may be more and more.

Discomfort. Discomfort may also cause a searcher to stop searching. For example, the following quote shows that users may feel uncomfortable as a result of long time working with computers for different purposes including searching the web.

> There are only a certain number of articles you can look at when you go through a PubMed search before your brain just glazes over, your eyes glaze over and you just skip and miss things.

Consequently, some of the interviewees mentioned that they were happy to be away from searching the web from time to time to avoid the tiredness of using it everyday:

> So, I do it [searching the web] at least once everyday except Sundays. That is when I garden. I turn it off and have a day without it, unless it is an emergency.

Boredom. Searching the web requires a certain degree of motivation and it cannot be continued when the searcher feels bored. For example, one of the participants found web searching a boring task to do and he mentioned that he personally likes the old fashioned way of looking for information through printed materials, and it makes him less motivated to carry on web searching unless he has to do it:

> It is rather boring, typing something in, and then getting something in return for information that you want . . . and I am also a bit an old fashioned guy. I really like to go to libraries and dig into books and stuff. Maybe I have the feeling this is a bit more special. Because everybody can go to the web and just type things in and look for it. But not everybody has skills to extract like hidden interesting references from the library.

Similarly, another interviewee said:

> Sometimes you might be unsuccessful not necessarily because it is not there but because you don't have the patience or time to actually keep looking.

Time limits. As has been mentioned before, time is a leading element that makes a big difference to users' search behaviour in terms of when to stop the search. The following quotes are examples of the importance of time in users' decision making:

> It depends how much time I have got. I suppose it is fairly obvious really. If I get the information, the depth of information that I want then obviously I treat it as a success. If I don't get to the depth that I want then I consider it to be a failure . . .

> I think I was doing it for about twenty minutes. I just think that was enough time to not get anywhere, because there're sorts of things to do. So, probably I gave up on a time limit.

Snowballing. According to Agosto, "snowballing" refers to a situation in which an individual begins to experience repetition or saturation in the information sources being found:

> Probably I always miss something. I think because we don't have, we never have to get everything. As long as I am satisfied with the products that I have found, that is it. I don't want anymore about it which might be same or similar or repetitive.

> I think when it comes to searching for literature, which I suppose it is something that I do quite a lot . . . you feel you get to a plateau when you are not finding many more references as

you read a paper and make a note about what they have cited. If you can start with something recent and you can go backwards . . . once you start finding the network of citations and you are not finding many more and you think okay well more or less I covered that area.

Perceptions of the volume and relevance of missed information

However, the concepts of bounded rationality and satisficing did not account for all aspects of the data relating to interviewees' search-related decision-making. Whilst there was evidence that searchers did experience these constraints, and did exercise the satisficing strategies, there was something more. By further analysis of the data, it was possible to:

- enrich the concept of the boundaries/constraints by injecting the perceived extent and consequences of stopping searching in terms of how much information might be missed and how important it might be to the problem that generated the information need; and
- elaborate the nature of satisficing behaviour specifically in relation to searching strategies.

Interviewees expressed their perceptions of the information they might be missing when they decide to terminate a search. These perceptions consisted of two dimensions: the likely volume of such "missed" information, and its importance. Figure 2 shows these two dimensions in the form of a matrix which is called in this paper "Matrix of Search Impact". The sections following the figure present interviewee quotations illustrating the different quadrants.

The "Inconsequential" zone

In the best situation, the "Inconsequential" zone, only a small amount of less relevant information is missed which does not affect the search performance considerably. An example quotation of interview texts for this zone is as follows:

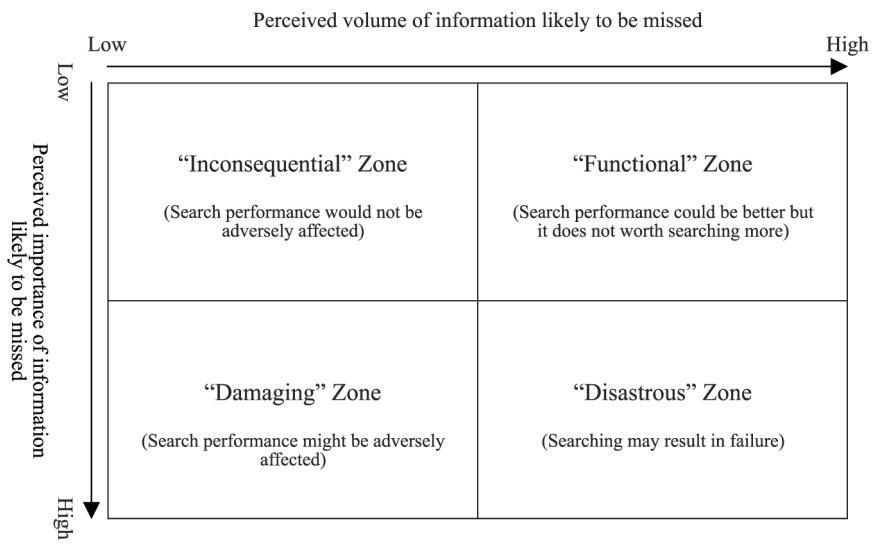

Figure 2. Matrix of search impact: searchers' perceptions of the volume and importance of possibly missed information

> There are probably things that it [search tool] misses but not too many. I don't think mainly because we work on certain organisms and it pulls up everything about them. So, it pulls up a lot of stuff which is completely spurious and tedious and in fact the numbers that I select to go into EndNote each week are probably about four or five out of the 150, but in fact that is a good hit rate I think.

The "Tolerable" zone

In the "Tolerable" zone, overlooking some relevant information does not lead to search failure but the result is not as satisfactory as it could be if the user had not missed those resources. In this zone which is more common in web searching missing the relevant information does not affect the search results because either there are alternative resources which are able to satisfy the user's information needs or the amount of the relevant found items are sufficient to achieve the search's goal. One of the interviewees describes this kind of search as follows:

> Basically I can usually get enough information to do my job. I might be able to get more information which might be enable me to do my job better but at the moment I still able to do my job well enough with the information that I get. So, it is sufficient. The word would be "sufficient". I think that describes my experience of using the web. It could be better but it does the job.

Therefore, in this zone, users do know that they are missing relevant information, which may be for a variety of reasons including the lack of sufficient time. Simply, they are not able to spend more time looking for it, or cannot afford access to fee-based resources.

The "Damaging" zone

In the "Damaging" zone users are concerned mainly about the relevance and importance of the missed information rather than its quantity. If the number of relevant documents is high then failure to retrieve a few highly relevant items might not affect the search performance drastically but if there are only a few highly relevant resources to fulfill the search successfully and the user misses the few possibilities it might lead to failure in search. Accordingly, in the "Damaging" zone search performance will be affected regarding the abundance of the relevant information. Here is an example of interview quotations which shows this situation:

> . . . there is a feeling that Oh! There are only six papers. Oh! I must have missed something. I mean obviously for papers you write for grants you have to be absolutely certain [about] what you've said. . . . then I will do some more related searches on related words just to check it doesn't bring up any other stuff . . . I mean there is only a feeling that I have missed a little bit, not a big feeling that there is only six papers on this, I am really missing a lot. It is more like, well there're only six papers better to do some check to see if there is only six.

Another interviewee mentioned even nowadays despite the availability of new methods of access to information, sometimes gaining access to some resources might be very difficult. As he was working in a very specialized field of biology he knew that missing some information items might has a damaging effect on his search because of the high importance of missed information:

> On the research side I think it can be a problem if you miss things that you know are important to your protein you work with and part of the problem is that some of these things,

> even now there's lots of journals, older articles in journals existing on paper that is very very difficult to get.

The "Disastrous" zone

In the "Disastrous" the user might miss a large portion of highly relevant information. This is the most severe situation of overlooking relevant information which might lead to search failure. As the quote below shows in specific cases missing relevant information can be disastrous:

> Missing the information is extremely important because if we miss, as we are moving to different scientific areas you have to read up all the background literature. If we miss an extremely important paper and that is very important to us because it might have that key piece of information which would have led us to make a new hypothesis or something. Particularly, when you are going to publish a paper or you are going to write a grant application . . . you cannot afford to miss any information.

One of the participants compared two search scenarios that in the second one she was worried that she might miss a very seminal item of information.

> I would say it depends on what I am searching for. Like say for the price of a ticket if I think this is good enough even though there is a cheaper ticket, okay I missed the cheaper ticket but that is not as such as a matter as you're missing a really important dataset that everybody knows about it except you.

Similarly, another interviewee said:

> If it is something that I am really desperate to find then of course it matters a lot if I just can't find it, it may waste my time and hold me up a lot and stop me to do something. Specially, if I am convinced that it is there somewhere.

Search satisficing strategies

In addition to the perceived consequences of stopping searching presented above, interviewees also spoke of their search strategies which could be classed in terms of two dimensions: the degree of effort expended by the searchers, and the perceived extent of missed information. These dimensions are shown as a matrix in Figure 3 which is called in this paper "Matrix of Search Depth". The sections below present interview quotations illustrating each of the zones.

"Perfunctory" searching

Sometimes users are not aware of missing information. In the "Perfunctory" zone users do not attempt to find any missed information because they are not aware of it. In this zone, users trust the results of their straightforward searches without worrying about the need to make them any more complex:

> When I am looking for things if I don't get anything then I am pretty certain that it is not there . . . if there is really useful information for me it is going to be on a reputable website where you can expect journals and these kinds of things. So, it is not going to be one of these things which are difficult to find. So, I think if you can't find stuff then generally it is because it is not there.

> I trust Google, if you want. So, if I type something in and Google doesn't find it I trust it is not out there. So, if I cannot find it so it is not my fault then. It is not there. So, in a way it seems

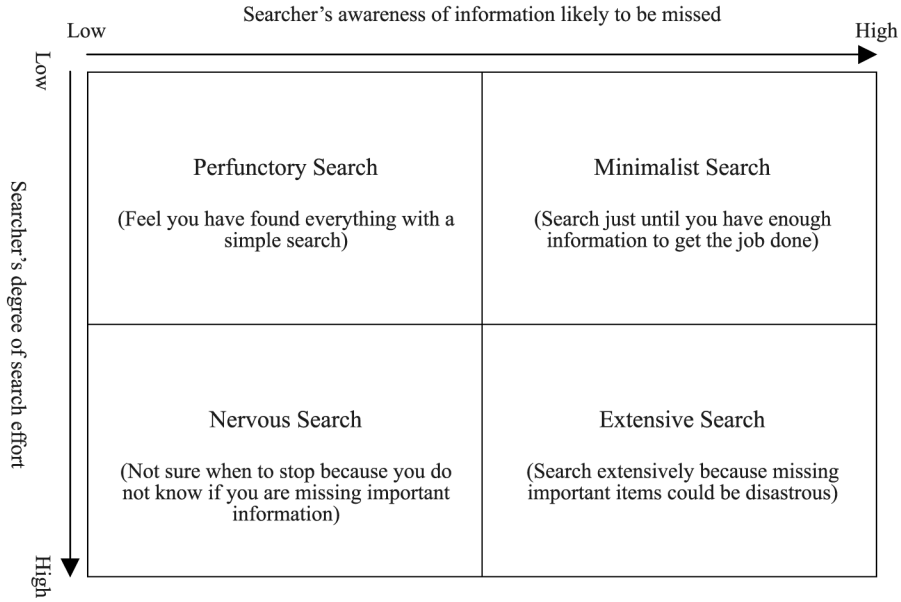

Figure 3.
Matrix of search depth: searchers' awareness of the possibility of missing relevant information and their determination to retrieve it

that I completely trust Google maybe I shouldn't. If I would not trust Google then I maybe more open to blame myself. That is true, yeah.

"Minimalist" searching

In the "Minimalist" zone, users are aware that they have probably missed some information but for various reasons they do not expend much effort to fill the gap. This kind of search is "minimalist" in that easily retrieved information fulfils the searcher's goal. The data in this study suggests that this is the most common type of web search:

> It is like, have you heard the metaphor "low hanging fruit"? It is like there is lot of low hanging fruit. There might be a lot of apples on the top of the tree but I don't need to get them because there are lots just hanging. I don't need to get my ladder.
>
> The criteria that I have are quite specific. So, there is a limited number of places that could actually fulfill those criteria. I am aware that I don't have all the answers and I don't get all the possibilities I don't get all, but I get enough for me to carry out my job . . . so, I don't try to get every last drop of information.

"Nervous" searching

Sometimes searchers may feel distinctly nervous that they may be missing important information. They do not know for sure whether they are, but fear doing so. Consequently, they are unsure of when they can safely stop:

> I don't always find what I am looking for and one of the biggest challenges is . . . it's hard to know, you never know, whether you can't find it because it is not there or if you can't find it because your search method is inappropriate. . . . You don't know when to stop, when to give up, because you don't know if you are wasting your time and there is literally no information out there online or whether you just not searched appropriately.

"Extensive" searching

In the "Extensive" zone, searchers consider it highly likely that they will miss important information if they fail to make extensive searching efforts. This kind of search is particularly appropriate in the case of, for example, literature reviews forming the basis for theses or research proposals. An example for this zone is as follows:

> I can see how people would think that missing something is a failure. If I am thinking say of a PhD student in the first year of their studies when typically they are doing their major literature survey. I am pretty sure they would feel they have failed if they missed getting 250 papers on a particular area they are working in because they're terrified they might be asked a question on it in their viva.

Discussion

In Figure 4, the correspondences between the different layers represent possible, and to some extent logical relationships. However, data analysis focusing specifically on these

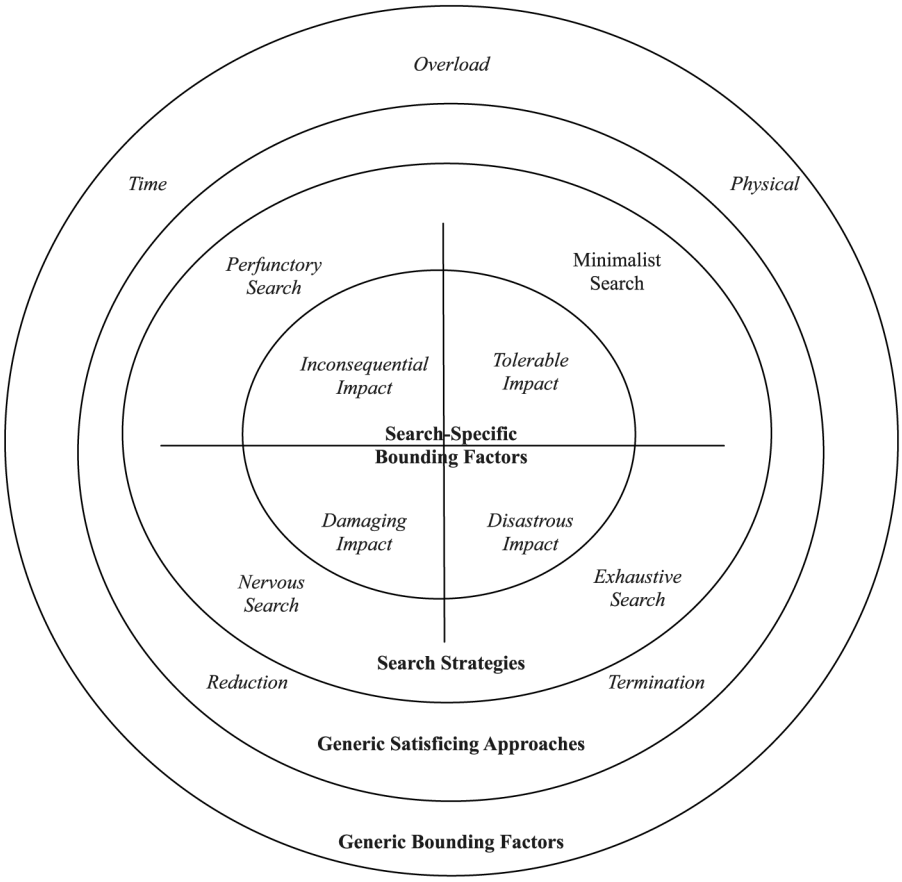

Figure 4. Model of information searching behaviour in the light of the theory of bounded rationality and satisficing

relationships has not to date been conducted, so this tentative mapping is not currently supported empirically. However, it is possible that there is some correspondence between:

- perceived "Disastrous" impact and "Extensive" searching, since dire consequences are likely to result from missing any important source;
- perceived "Damaging" impact and "Nervous" searching since, if an extensive search is not to be attempted, there may be uncertainty about when to stop searching coupled with worry about potentially damaging results of so doing;
- perceived "Tolerable" impact and "Minimalist" searching, since the retrieval of "low hanging fruit" is likely to be acceptable; and
- perceived "Inconsequential" impact and "Perfunctory" searching since there is low perceived likelihood of any adverse consequences resulting from relatively shallow searching.

Search-specific bounding factors are likely to interact with generic ones, with certain ones over-riding others. For example, physical and/or psychological discomfort or boredom may be over-ridden where the impact of missing information is perceived as potentially disastrous. In such circumstances, strenuous attempts may also be made to overcome time limitations. This would be much less so where the possible impact of missing information is less deleterious.

Different search strategies may render different satisficing approaches more or less relevant. For example, in the context of an extensive search snowballing (or saturation) becomes particularly appropriate since it may be an indicator of the completeness of a search. Conversely in this context, factors such as boredom and physical discomfort should be less relevant. In the context of an minimalist search, snowballing is likely to be less appropriate, and physical and/or psychological factors may be perceived as more influential.

The study reported here raises a number of questions and arguably has a number of implications. In terms of further research, it would be interesting to explore the extent to which the mappings shown in Figure 4 are supported by empirical data. It would also be useful to test the robustness of the constructs identified within the small scale qualitative study reported here by using larger-scale statistical survey techniques. If found to be robust, it would then be interesting to discover:

- What is the incidence within particular populations of different generic and search-specific bounding factors and satisficing strategies in relation to web searching.
- What is the incidence of inappropriate use of search satisficing approaches, and what might be the effects of this. For example, effectiveness would be compromised were a young person to consider a "perfunctory" search as entirely appropriate (or possibly the only known) strategy in the context of schoolwork requiring a deeper analysis. Similarly, compromised in terms of quality would be the undergraduate using a "minimalist" approach to deliver some low hanging fruit when what is required is a more critical comparative analysis – for which a wider-ranging search may be more appropriate.

- Whether some people use multiple satisficing approaches and if so, how these interact, and whether certain approaches and interactions between approaches are more effective than others.
- What might be, if any, the effects on choice of satisficing strategies – and the effectiveness of this choice – of levels of prior knowledge of the search subject domain on the part of the searcher.
- What might be, if any, the effects of individual factors such as cognitive style. Are different search satisficing approaches favoured, for example, by searchers with a more impulsive as opposed to more reflective style, or a more dependent as opposed to autonomous thinking style, or a more sequential as opposed to holistic thinking style?
- What might be, if any, the effects of age and education on the selection and use of appropriate and effective approaches? Do people's knowledge and choice of strategies develop in range and/or effectiveness over time? Or do some people become entrenched in comfortable (if ineffective) approaches?
- To what extent different people and/or groups are aware of the range of possible approaches and their implications.

Perhaps, the most interesting, yet at the same time most problematic question relate to the extent to which perceptions map onto "reality". Clearly, any attempt to assess how "accurate" a searcher's perceptions are (of information that might be missed, and of how importance this information might be), and how "appropriate" and "effective" are their decisions when to stop searching, bring into relief the essentially subjective and constructivist nature of these concepts. Nevertheless, it may be useful to attempt to obtain relatively objective assessments – for example, by pooling the ratings of a number of expert judges, against which to rate individual searchers' perceptions. Even if the differences between the two are far from accurate in any absolute sense (indeed such accuracy would arguably be impossible to attain given the subjective nature of relevance and the infeasibility of measuring recall within a web context) they may nevertheless be useful in terms of helping less experienced searchers move in a beneficial direction.

Indeed, the mapping of an individual searcher's perceptions against more objective assessments may be useful in the context of information literacy education and training. It could be instructive to know, at least to a degree, the extent and importance of information likely to be missed within the context of different satisficing approaches and related search strategies. The study reported here also raises a number of questions within the context of LIS practice. In particular, it could be beneficial to know:

- Whether, and if so how, we can help people develop more effective satisficing approaches.
- The extent to which an important component of information literacy is to know when to stop searching.
- The extent to which "critical searching" is needed to provide the raw materials for critical thinking. In certain contexts, critical thinking nurtured on low hanging fruit may be stunted.

- Whether we can educate people to move away from what for them might be overly comfortable and possibly entrenched approaches where these are inappropriate.
- How can we help searchers, where appropriate, be aware of the ineffective use of particular approaches (e.g. the use of perfunctory and minimalist strategies where something more extensive is required).
- How can we help searchers – particularly "nervous" and "extensive" searchers – to know when it is safe to stop searching. It may be useful to attempt to develop quality filters such as those used in medical search facilities whereby the highest quality sources are listed first. Therefore, a searcher could see where the quality had dropped to a certain level and could take the decision to stop searching with more confidence and less uncertainty. Cleary, the notion of "quality" is arguably less problematic in areas such as medicine where "gold standards" of quality can be agreed.

Concluding remarks

The risk of missing potentially important information was a matter of concern to the interviewees in the study reported here. It is interesting that they had varying views on the extent and potential value of information that they thought they might be missing – as opposed to expressing any universal ignorance. The ways in which they went about searching, and the ways in which they went about deciding when to stop searching, showed considerable variation.

It is also interesting that the scheme developed by Agosto (2002) for coding interviews with a very different sample (ninth- and tenth-grade schoolchildren) and in relation to different web-based information behaviour (evaluating websites rather than specific searching) mapped well onto the data here. It would appear that there is at least a *prima facie* case for bounded rationality and satisficing being considered as potentially useful concepts in our quest better to understand aspects of human information behaviour.

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Appendix 1. The interview main schedule

Q1. What is your general feeling about searching the web? How do you find it in general?
Q2. How long have you been searching the web?
Q3. How often do you search the web?
Q4. What kind of information do you usually look for on the web?
Q5. How satisfactory are search results for you in general?
Q6. Can you remember and describe one of your recent experiences in which you were successful in web searching?
Q7. Why do you think in this specific case you have been successful?
Q8. Do you always manage to find what you want on the web or do you ever not find what you have been looking for?
Q9. Can you remember and describe one of your recent experiences in which you failed to find what you have been looking for?
Q10. Why do you think this specific case was a failure?
Q11. How do you feel about your information seeking failure on the web?
Q12. How do you differentiate between failure and success in searching the web?
Q13. Do you ever get the feeling that there should be more relevant information about your search topic on the web but you are not getting to it?
Q14. Do you think that you always find everything that exists on your search topic on the web? I mean, in your opinion how likely is it that you have missed something about your search topic? If so, why could not you find it?
Q15. How much does it matter to you if you know you have missed something while searching the web? How do you feel about it? ... Do you always feel like that?
Q16. When you fail to find what you want on the web, what do you do about it? I mean, how do you seek different solutions to cope with information seeking failure on the web?
Q17. How did you develop these coping strategies?

Before ending the interview, I need to clarify two more things:
Q18. What does the web mean to you? I mean, what do you mean by the web?
Q19. Could you describe what "The Invisible Web" might mean to you?
Q20. Is there anything else that you would like to add?

Corresponding author
Yazdan Mansourian can be contacted at: y_mansourian@yahoo.com

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