

# Best Practices and Future Visions for Search User Interfaces

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**The authors describe a set of best practices that were developed to assist in the design of search user interfaces. Search user interfaces represent a challenging design domain because novices who have no desire to learn the mechanics of search engine architecture or algorithms often use them. These can lead to frustration and task failure when it is not addressed by the user interface. The best practices are organized into five domains: the corpus, search algorithms, user and task context, the search interface, and mobility. In each section the authors present an introduction to the design challenges related to the domain and a set of best practices for creating a user interface that facilitates effective use by a broad population of users and tasks.**

## Introduction

Search user interfaces have been designed for a variety of task types. Early in the digital era, mostly expertly trained users used some of the first user interfaces to search large databases in corporations, governments, and libraries (Rappaport, 2002). These interfaces were complex and powerful. They allowed users to input compound Boolean queries so that the results would closely match the needed data. Interfaces for these complex information retrieval (IR) systems continue to advance as new ideas in usability are identified.

When IR systems became accessible to the largely novice masses, existing search user interfaces proved to be overly complex. Supporting public access in the library was an early challenge but in that environment, experts were usually available to provide assistance. Web-based search engines that were usually accessed from home needed to be simple enough for the entire population to use with minimal assistance. However, in one study of Internet searching, only 18% of users reported that they could find what they were looking

for on the Web (Search Engine Watch, 2000). Also, 67% said they were frustrated when searching. In Sullivan (2000), 21% of the respondents reported being able to find what they were looking for *every time*, and only 60% reported finding the relevant information *most of the time*. Additional challenges were faced when search capabilities were added to mobile devices that had small screens and limited bandwidth. As technology adapts to meet the varied environments in which searching is demanded, search interfaces must continue to evolve. The challenge is to retain the power of early systems while allowing novice users to achieve their search goals.

The term *best practices* suggests that certain design ideas have shown a modicum of superiority to other ideas and have been adopted by respected practitioners in at least some circumstances. Best practices begin by considering whom the users are and what they will need to do with the system. In general, they involve treating system design as an ongoing and iterative process, consistently looking for improvement and fine-tuning as users and their needs change over time. Best practices include vigilance to take advantage of new technologies (i.e., algorithms and system capabilities) that might offer new capabilities yet unconsidered by end users.

Here we present a summarization and synthesis of ideas that were developed during a collaboration of many leading search user-interface designers and researchers (the CHI 2003 Conference Workshop “Best Practices and Future Visions for Search User Interfaces” at the Conference on Human Factors in Computing Systems, Ft. Lauderdale, FL, April 5–10, 2003); hence, we feel these ideas represent best practices. This set of search design best practices can be divided into five domains:

- The structure of the corpus (i.e., the knowledgebase to be searched)
- The algorithms used to parse the corpus and match queries with content
- The user context and requirements of the search task

- The interface between the search system and the user (e.g., Web browser, desktop user interface)
- The emergence of hardware and bandwidth challenges of mobile devices

We will briefly discuss each of these domains and describe some best practices. For more information, refer to the rest of this issue's articles and other publications by the authors featured here, as well as that of other designers who did not participate but who have developed many best practices.

## The Structure of the Corpus

The mechanisms of search are intricately dependent on the structure of the corpus. One of the extreme challenges of Internet-wide search engines is that the target content is designed without any overarching structure, and, in fact, parts are designed intentionally to lack structure (Brooks, 2001). However, for site-specific search systems, it is possible for search and content designers to cooperate and create a structure that supports a simple location of content. Understanding the nature of the corpus is essential before designing an effective search system.

### *Corpus Characteristics*

An obvious distinction for any search system is whether it searches the entire Internet, is limited to a single domain or cluster of domains (i.e., all medical sites), or searches a database with known structure. This distinction is important because of the assumptions that follow. Systems that search the entire Internet can make few assumptions about the nature of the content whereas those that are limited to specific areas may be able to take advantage of regularities in the content.

Another characteristic that should be used to drive the design of a search user interface (UI) is the diversity of information contained within the corpus. Even when search systems parse only a single site, the diversity of information can range widely. For example, the corpus covered by the Digital Library for Earth Science Education (DLESE; see Davis, 2006, pp. 788–791) is consistently structured and can take advantage of a controlled vocabulary. On the other hand, the content at AOL's ecommerce site (see Gremett, 2006, pp. 808–812) is significantly more diverse. This increases the likelihood of false alarms and reduces the ability to use controlled vocabularies and metadata.

## Content Characteristics

One structural notion that has received a lot of attention recently is the concept of faceted metadata. Content-oriented metadata refers to tags assigned to units of content that describe it along predetermined dimensions. Metadata is faceted when these dimensions are orthogonal (Yee, Swearingen, Li & Hearst, 2003). Metadata can also be hierarchical or multivalued (a unit of content can have more than one tag for a given facet) when appropriate (Yee et al., 2003). Studies by English, Hearst, Sinha, Swearingen, and Yee (2002) and Yee et al. (2003) show that users respond positively to searches using faceted metadata.

Content clustering can also be used to improve the integration of content design and search. Howard (2003) defines clustering as using statistical techniques to group content units by similarity. He also describes vector-based systems that represent content units as arrows on a multidimensional graph and using physical proximity to identify similarity.

Whatever structure is used, any system that includes metadata must consider what fields are relevant. In general, the selection of fields should consider all the tasks that users may attempt. Fields can include domain-specific characteristics as well as geographic, language, chronological, and other universal criteria.

### *Best Practices Related to the Corpus Structure*

- When designing a search system that is limited to a controlled corpus, faceted metadata should be attached to content units.
- As the size of the corpus increases and as the sophistication of the user decreases, the need for corpus structure increases.
- Content clustering can be used to identify relationships within the corpus. These relationships can be presented to the search system user to assist in iterative search and browsing search results.
- Fields used to create metadata or content clusters should consider user requirements gathered using best practice methods.

## Matching Algorithms

Regardless of how comprehensive or well organized a corpus is, without an effective algorithm to match queries with specific units of content, searches cannot be successful. There are many challenges to creating a successful matching algorithm, some in the mathematical domain and others in the human factors domain. In this section we will focus on the human factors.

Many hypotheses have been proposed to explain the short, nonspecific, and error-ridden queries that have been identified in search log analysis (Jansen & Pooch, 2000). Nevertheless, whether the cause is a deficiency in the user's lack of search experience, domain knowledge, attention to the task, or another reason, an effective search UI needs to determine the user's intention at least well enough to identify the relevant content in the corpus. Several best practices for doing this have been proposed.

The most basic methods are spell checking and approximate word matching. These involve using algorithms to identify words in the query that are misspelled (see Rappaport, 2002) or have multiple spellings, such as "colour" (French, Powell, & Shulman, 1997). The matching algorithm then includes these alternatives in the query.

Query expansion and contraction are two common methods. Expansion involves adding synonyms and other related words to a query to increase the number of matches that are identified. Three types of query expansion have been described (Gauch & Wang, 1997). *Query-specific expansion* is conducted as part of an iterative search. Initial results are compared for similar keywords and the user is asked to identify additional words in those results to add to the query.

*Corpus-specific expansion* only adds terms that are related within the context of the corpus. No additional action by the user is required. *Language-specific expansion* is the most general and includes any terms that are synonymous with terms currently in the query. This is most useful for Internet-wide searches.

*Query contraction* involved disambiguating any terms with multiple meanings to insure that only relevant matches are returned. For Internet-wide searches, user response is necessary. For domain-specific searches, meanings that are related to the corpus can be given priority over meanings that are not related.

For any query transformation, it is critical to make the transformation transparent to the user (Muramatsu & Pratt, 2001). This allows the user to verify that the transformation is appropriate and may allow the user to learn more effective query formulations.

Zhou and Zhang (2003) propose applying natural language processing to queries to improve the match. They describe several modeling techniques ranging from word-level analysis such as stemming and spell checking to document-level analysis including linguistic analysis of the query and the content units of the corpus. They also allude to future methods such as defining the role that keywords play in a document relative to the domain.

Perry and Chu (1997) describe a process termed *content-part linking* that involves a semantic decomposition of each content unit and the development of a matrix portraying the relationships among units. Searches would entail navigating through the content, with each step identifying content that more closely matches the search goal.

Unfortunately, many techniques that usually improve match quality can also degrade it. Disregarding stop words (such as “the”) from a query usually lead to better matches. However, a search for “Vitamin A” that eliminates the word “A” would clearly lead to an overwhelming number of false alarms (returned hits that are not specific to this query). Bates (2003) exposes a limitation of query expansion. Often, alternative meanings of a term for a particular task are not the same as those found in traditional thesauri. Identifying these meanings can be a challenge.

#### *The Best Practices Related to the Matching Algorithm*

- Spell check all terms in a query for an Internet-wide search.
- Use domain-specific dictionaries and thesauri for spell checking and query expansion algorithms for a corpus-specific search.
- Consider document-level expansion using semantic and syntactic modeling for a corpus-specific search.

### **User Context and Task Requirements**

#### *Search Types*

Search is generally a very applied and context-specific activity. Several kinds of search have been identified. The search type used for a particular search task will depend on

many of the task characteristics described in this section. Search types include (Hearst et al., 2002):

- *Directed search*: The search for specific items or facts, such as “KDS Radius 15” flat panel monitor” or “the population of France in 1996.”
- *Comparison*: The search for specific information about multiple items for comparison purposes, such as “selecting a cellular phone plan.”
- *Informal Browsing*: The search for general information about a topic, such as “landscaping a backyard.”
- *Text mining and analysis*: The search for comprehensive information about a particular topic, such as “promising treatments for cancer.”

Thatcher (2000) also differentiates top-down search strategies, where the user begins with a general search term and identifies more specific keywords from the results, and bottom-up search strategies, where the user starts with a set of specific keywords and expands the search until a sufficient number of results are found. Thus, search activities combine search tasks and browse tasks. A strict dichotomy between searching and browsing does not seem to represent most search activity. While some users start immediately with one or the other, the majority of searches alternate between the two modes as the search progresses. In addition, any one search session might involve all four types of searching.

In a study comparing search behavior using a variety of task types, Rouet (2003) found that a more specific information need leads to skimming with long pauses for results that reach a match threshold. A more general information need results in more frequent pauses and more navigation back and forth between content units.

Aspects of the specific task can also affect the search process. The requirements of search tasks can range broadly across a variety of dimensions. For example, the time available to complete the task can affect the user’s search behavior. Time pressure can reduce the amount of thought users expend on developing a query, thus reducing the complexity of the query. Users may also be quicker to select a content unit from the results list, perhaps choosing one of lower quality that happened to be higher on the list. The importance of the task will have the opposite effect. Tasks of high importance can increase the time allocated to creating an appropriate query, evaluating the alternatives, and navigating among them.

#### *The User*

There are also many characteristics of the user that affect the search task. Some characteristics are durable, describing the user for all search tasks. Others depend on the task, such as the user’s domain knowledge in the subject being searched.

Domain knowledge affects the strategies used to search. Jefferson and Nagy (2002) report that the probability that both a searcher and search system will apply the same term for a given concept is only 10–20%. Navarro-Prieto, Scaife,

and Rogers (1999) found that domain experts begin with a structured understanding of their task and can use this structure to select appropriate keywords. Domain novices begin with externally derived keywords and rely on iterative search processes to refine the search query. Rouet (2003) found that domain novices rely more on navigation within content units than domain experts do.

Expertise with search tasks in general can also affect search behavior. Shneiderman (1997) suggests that novices look at the interface and develop a plan based on the widgets visible on the page. Experience may determine a user's willingness to use these widgets. Widgets or functionality that did not improve use are less likely to be used again. This may be independent of the search system, so if users were unsuccessful with particular functions on previous systems, they may be unwilling to try the same function on a new system.

There are also interactions with domain knowledge and search expertise. An empirical study by Holscher and Strube (2000) evaluated the search queries of both domain and search novices and experts. They found that while search expertise increased the likelihood of using operators such as Boolean and adjacency, domain expertise decreased this likelihood. A similar study by Proper and van der Weide (2001) suggested that the queries constructed by users with high domain knowledge but low search expertise can be dominated by keywords and have unsophisticated operators or structure.

The basic demographic and psychographic characteristics of the user may also have an effect on search behavior. While little research has focused explicitly on the effects of user age, gender, or other factors, it is important to consider these when designing a search system to account for any variation that may appear. Research is needed to elucidate the effects and interactions of these user characteristics.

### *The Environment*

The environment in which a search is conducted can constrain the design of the search system. Some emerging models of contextual search consider search tasks that the user has previously conducted to inform query expansion or contraction. Frucht, Kreuniger, and Beigl (1997) describe a search assistant that models the user's search history and uses this model to improve future queries. Shneiderman, Byrd, and Croft (1997) also recommend using search histories to improve query formulation and refinement. However, this type of system can only work when searches are being conducted from a consistent location or if the profile is stored in an accessible location. Furthermore, the benefit of using search history is very time dependent. The likelihood that a past query is relevant to the current search is inversely related to the time that has passed since the previous query was used.

Query improvement can also consider other tasks conducted concurrently by the user. Semantic modeling of other documents that are open on the user's desktop can be used in this way. Privacy concerns may arise in this case, so use of these practices must reside under the control of the user.

### *The Best Practices for Addressing Issues Related to the Search Task*

- Search and browse styles should be provided to support hybrid navigation within the search results.
- The user should remain in control of how much context is included in the search query (for privacy reasons as well as because current algorithms incorrectly interpret context).
- Search UIs can be customized to reflect the domain or system expertise of the current user.
- Past search queries can be used to frame the current need, but this should be heavily weighted in favor of recent queries.

### **Search User Interface**

The design of the interface in which the user interacts with the search system can have significant effects on the search behavior (Navarro-Prieto et al., 1999). All universal best practices for human-computer interface design should, of course, be considered. In addition, there are many design ideas that have been studied specifically for search user interfaces. The aspects of the user interface can be divided into three categories: the input interface, the output interface, and support for iterative searching.

#### *Input*

The variety seen in search user interfaces reflects both the challenge of designing effective Web sites and the competing objectives of many search systems. Simple ideas such as increasing the size of the text input box to encourage users to input longer queries have shown some promise. Unfortunately, more advanced features are not generally used. A review by Jansen and Pooch (2000) lists several log analysis studies that found very little use of Boolean operators and other advanced features. Bandos and Resnick (2002) gave users a task that required the use of compound queries, but found that users still did not use the advanced features to assist them.

A recent study by Bandos and Resnick (2004) found that users generate more effective queries and are more satisfied with interfaces that contain brief guidance on search syntax and semantics. These were provided in the form of search "hints," located adjacent to the search query input box. However, the presence of these hints slightly increased the time required to complete the search task.

#### *Output*

The traditional search system output is a list of results including the fields that the search designer anticipates being the most important. Some fields, such as a title or description of the content unit are important for the majority of tasks, while others should be customized for the current user need (Resnick & Lergier, 2003). Alternatives to the list format include thumbnails (Woodruff, Faulring, Rosenholtz,

Morrison, & Pirolli, 2001) and tables (Resnick, Maldonado, Santos & Lergier, 2001).

There has been some debate over how many results to include. Longer lists may not improve user performance, particularly when considering that most users do not review more than the first one or two pages of results (Jansen & Pooch, 2000). With best match algorithms, adding more keywords to the queries increases the number of results whereas with standard algorithms, more keywords lead to fewer results. This difference should be made explicit to the user (Muramatsu & Pratt, 2001).

When the number of results exceeds manageable levels or contains different kinds of results, the list can be divided into separate categories or folders (Silverman, 2001). This allows users to direct their attention to the results that best match their needs. Dividing results into folders is facilitated when the corpus has faceted metadata to use as the categories.

The inclusion of relevance rankings and scores has also been debated. While some authors have advocated use, others suggest that they are not used (Jansen & Pooch, 2000). Perhaps, they would be used if they were designed to be usable and effective (Hearst et al., 2002).

### *Iteration*

Searching is often an iterative process, requiring modification of earlier queries as the user gains information about the corpus and the success of initial keywords. An iterative search can be supported in a variety of ways.

Lundquist, Grossman, and Friedler (1997) discuss several ways that users can improve their queries based on a review of the results list from an initial query. Users can add new keywords that occur in content units that are assessed as close to the goal. They can also weight keywords that seem to retrieve quality results. Fang and Salvendy (2001) suggest that a search system can allow users who may not have the expertise to manipulate keywords simply to highlight phrases in the results descriptions and the system can identify mutual keywords automatically.

Users should be allowed to search in a variety of ways during subsequent iterations. They can be allowed to search only within the results of a previous query or a subset of these results. This facilitates a faster narrowing of the results set. They can also be supported in searching across the results—using a subset of the current results as a link to additional information.

### *The Best Practices in Search User Interface Design*

- Provide a large query entry box when longer queries will be effective.
- Brief search hints are more likely to be used than advanced search dialogs.
- In the results descriptions, show the keywords in context.
- Organize large sets of results into categories.
- If no results are found, provide suggestions for improving the query.

- On the results page, provide the original query in a format that can be edited.
- The user interface should facilitate iterative searching by supporting the modification of queries and allowing users to search within and across existing results sets.

## **The Challenges of Mobility**

Mobility adds a significant challenge to the design of search systems. Most mobile devices have limited bandwidth and small screens, therefore necessitating a different approach to search system design. Because of the challenges encountered, Jones, Buchanan, and Thimbleby (2003) recommend the content designers should create versions of their content specifically for viewing on small screens.

One challenge is the tradeoff that arises when considering the two major limitations of the mobile device. The smaller screen suggests that the search user interface should contain less information than a full-screen design so users do not have to scroll excessively. However, the limited bandwidth suggests that more information should be provided so users do not have to switch between pages excessively. Jones et al. (2003) resolve this tradeoff with the recommendation to include more information. They suggest that scrolling is less severe than switching pages.

### *The Best Practices for Search on Mobile Devices*

- When possible, design alternate versions of content specifically for mobile devices.
- When content cannot fit within the constraints of the screen, scrolling is better than switching between pages.
- When scrolling is necessary, use vertical rather than horizontal scrolling.

## **Going Forward**

From the CHI 2003 Conference Workshop “Best Practices and Future Visions for Search User Interfaces,” the International Working Group for Search User Interfaces (IWGSUI) was created. This is an ongoing academia–industry collaboration to identify search user-interface best practices and facilitate the constant improvement of search. Current efforts include:

- The development of user scenarios to illustrate the variety of environments in which searches are conducted.
- The collection of design case studies to illustrate and discuss concepts for search UI design and the challenges that arose during their creation.
- The compilation of an annotated bibliography to aggregate a variety of research results and other publications in search UI design and critically evaluate their application to various search domains.

The working group also plans future activities such as:

- The collection of design patterns to illustrate solutions for search UI and the specification of where and why they should be used.

- The development of packaged presentations that can be used by designers or researchers to promote effective search UI design and/or solicit funding for research in search.
- The creation of partnerships between organizations that have specific needs for search research and development assistance with organizations able to provide these services.

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## References

- Bandos J., & Resnick, M.L. (2002). Understanding query formation in the use of Internet search engines. In Proceedings of the Human Factors and Ergonomics Society 46th Annual Conference (pp. 1291–1295). Santa Monica, CA: Human Factors and Ergonomics Society.
- Bandos, J., & Resnick, M.L. (2004). The effects of semantic and syntactic instruction on user performance and satisfaction in search user interface design. Proceedings of the Human Factors and Ergonomics Society 48th Annual Conference. Human Factors and Ergonomics Society.
- Bates, M.J. (2003). After the dot-bomb: Getting web information retrieval right this time. *First Monday*, 7, 7, 1–10. Retrieved March 13, 2003, from [www.firstmonday.org/issues/issue7\\_7/bates/](http://www.firstmonday.org/issues/issue7_7/bates/)
- Brooks, T.A. (2001). Where is meaning when form is gone? Knowledge representation on the Web. *Information Research*, 6, 2. Retrieved January 12, 2004, from <http://InformationR.net/ir/6-2/paper93.html>
- Davis, L. (2006). Improving Internet interaction: From theory to practice. *Journal of the American Society for Information Science and Technology*, 57, 788–791.
- English, J., Hearst, M., Sinha, R., Swearingen, K., & Yee, K. (2002). Hierarchical metadata in site search interfaces. In Proceedings of CHI 2002 Interactive Posters (pp. 628–629). New York: ACM.
- Fang, X., & Salvendy, G. (2001). Keyword comparison: A user-centered feature for improving web search tools. *International Journal of Human-Computer Studies*, 52, 915–931.
- French, J.C., Powell, A.L., & Shulman, E. (1997). Applications of approximate word matching in information retrieval. In Proceedings of the 6th International Conference on Information and Knowledge Management (pp. 9–15). ACM: New York.
- Frucht, M., Kreuniger, J., & Beigl, M. (1997). Assistant for an information database. In Proceedings of the 6th International Conference on Information and Knowledge Management (pp. 230–237). ACM: New York.
- Gauch, S., & Wang, J. (1997). A corpus analysis approach for automatic query extension. In Proceedings of the 6th International Conference on Information and Knowledge Management (pp. 278–284). ACM: New York.
- Gremett, P. (2006). Utilizing a user's context to improve search results. *Journal of the American Society for Information Science and Technology*, 57, 808–812.
- Hearst, M., Elliott, A., English, J., Sinha, R., Swearingen, K., & Yee, K. (2002). Finding the flow in web site search. *Communications of the ACM*, 45(9), 42–49.
- Holscher, C., & Strube, G. (2000). Web search behavior of internet experts and newbies. In Proceedings of the 9th International Conference of the WWW Consortium. Cambridge, MA: W3C.
- Howard, D. (2003, January). You are here. *New Architect*, 1–6. Retrieved January 28, 2003, from [www.newarchitectmag.com/print](http://www.newarchitectmag.com/print)
- Jansen, B.J., & Pooch, U. (2000). Web user studies: A review and framework for future work. *Journal of the American Society of Information Science and Technology*, 52(3), 235–246.
- Jefferson, T.I., & Nagy, T.J. (2002). A domain-driven approach to improving search effectiveness in traditional online catalogs. *Information & Management*, 39, 559–570.
- Jones, M., Buchanan, G., & Thimbleby, H. (2003). Improving web search on small screen devices. *Interacting with Computers*, 15, 479–495.
- Lundquist, C., Grossman, D.A., & Friedler, O. (1997). Improving relevance feedback in the vector space model. In Proceedings of the 6th International Conference on Information and Knowledge Management (pp. 16–23). ACM: New York.
- Muramatsu, J., & Pratt, W. (2001). Transparent queries: Investigating users' mental models of search engines. In Proceedings of the 24th International ACM Conference on Research and Development in Information Retrieval. Retrieved January 12, 2004, from <http://www.ics.uci.edu/~pratt/pubs/SIGIR-TQ.pdf>
- Navarro-Prieto, R., Scaife M., & Rogers Y. (1999). Cognitive strategies in web searching. In Proceedings of the Human Factors & the Web Conference. Gaithersburg, MD: National Institute of Standards and Technology.
- Perry, B., & Chu, W.W. (1997). Discovering similar resources by content part linking. In Proceedings of the 6th International Conference on Information and Knowledge Management (pp. 317–324). ACM: New York.
- Proper, E., & van der Weide, T. (2001). Information coverage: Incrementally satisfying a searcher's information need. In C. Stephanidis (Ed.), Proceedings of the Universal Access in HCI Conference (pp. 719–723). Mahwah, NJ: Erlbaum.
- Rappoport, A. (2002, March). Web search engines: Users surprising the experts. A presentation to the BayCHI special interest group. Retrieved June 12, 2002, from <http://www.searchtools.com/info/slides/baychi2002/index.html>
- Resnick, M.L., Maldonado, C.A., Santos, J.M., & Lergier R. (2001). Modeling on-line search behavior using alternative output structures. In Proceedings of the Human Factors and Ergonomics Society 45th Annual Conference (pp. 1166–1170). Santa Monica, CA: Human Factors and Ergonomics Society.
- Resnick, M.L., & Lergier R. (2003). Task specific user strategies in on-line search. *Journal of E-Business*, 3, 1, 1–22.

- Rouet, J.F. (2003). What was I looking for? The influence of task specificity and prior knowledge on students' search strategies in hypertext. *Interacting with Computers*, 15, 409–428.
- Search Engine Watch. (2002). The Search Engine Report. Search satisfaction and behavior results. Retrieved August 13, 2002, from <http://www.searchenginewatch.com/sereport/00/04-npd.html>
- Shneiderman, B. (1997). Designing information abundant web sites: Issues and recommendations. *International Journal of Human Computer Studies*, 46, 1–21.
- Shneiderman, B., Byrd, D., & Croft, W.B. (1997, January). Clarifying search. Retrieved November 5, 1998, from [www.dlib.org/dlib/january97/retrieval/01shneiderman.html](http://www.dlib.org/dlib/january97/retrieval/01shneiderman.html)
- Silverman, B.G. (2001). Implications of buyer decision theory for design of e-commerce websites. *International Journal of Human-Computer Studies*, 55, 815–844.
- Sullivan, D. (2000). NPD Search and Portal Site Study. Retrieved August 13, 2000, from <http://www.searchengine-watch.com/reports/npd.htm>
- Thatcher, A. (2000). Experience and WWW searching, or the search for the WWW "expert." In *Proceedings of the IEA 2000 HFES 2000 Congress*. Santa Monica, CA: Human Factors and Ergonomics Society.
- Woodruff, A., Faulring, A., Rosenholtz, R., Morrison, J., & Pirolli, P. (2001). Using thumbnails to search the web. In *Proceedings of SIGCHI '01*. New York: ACM.
- Yee, K.P., Swearingen, K., Li, K., & Hearst, M. (2003). Faceted metadata for image search and browsing. In *Proceedings of CHI 2003* (pp. 401–408). New York: ACM.
- Zhou, L., & Zhang, D. (2003). NLPIR: A theoretical framework for applying natural language processing to information retrieval. *Journal of the American Society for Information Science and Technology*, 54(2), 115–123.