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Why are Online Catalogs Hard to Use? Lessons Learned from Information-Retrieval Studies

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Research in user behavior on online catalogs is in its early stages, but preliminary findings suggest that users encounter many of the same problems identified in behavioral studies of other types of bibliographic retrieval systems. Much can be learned from comparing the results of user behavior studies on these two types of systems. Research on user problems with both the mechanical aspects and the conceptual aspects of system use is reviewed, with the conclusion that more similarity exists across types of systems in conceptual than in mechanical problems. Also discussed are potential sources of the problems, due either to individual characteristics or to system variables. A series of research questions is proposed and a number of potential interim solutions are suggested for alleviating some of the problems encountered by users of information systems.

Introduction

Online catalogs and multidatabase bibliographic-retrieval systems have evolved independently, with different searching capabilities to offer and different groups of users to serve. These distinctions have begun to blur, both in the areas of design and of population served. Online catalogs are becoming increasingly sophisticated, adding capabilities such as Boolean searching and index browsing. Commercial systems are simplifying command structures (e.g., the Dialog2 improvements) and offering less complex interfaces for end users (e.g., Dialog's Knowledge Index, BRS Brkthru, BRS/After Dark). Increasingly, the commercial systems are aiming their marketing directly at the end users of the systems (Marovitz [85] and Williams [126]). Even the distinction between online catalogs as one-database systems and bibliographic-retrieval systems as many-database systems is fading as online cat-

alog systems add other bibliographic databases such as Medline (Brownrigg and Horres [29] and Broering [28]), and as more small systems with a limited number of specialized databases appear (Cuadra Associates [36] and Williams [126,127]). Even the database contents are becoming more similar, as commercial systems add monographic cataloging databases to their offerings [e.g., LC/Line on SDC Orbit, EASI (OCLC records) on BRS, Library of Congress MARC Books File on Wilsonline].

In spite of the convergence of these systems, most studies of their use have viewed them independently. Researchers have focused either on online catalogs (those used in libraries for public access by patrons) or on bibliographic retrieval systems (publicly available systems, such as Dialog, BRS, Orbit, Medline) as a class; findings from studies of one class rarely have been applied to the other. The separateness of research has been especially strong in studies of user behavior, although many of the findings are similar. Each is a rich literature, and much can be learned by comparing the findings.

This paper briefly reviews the literature on user studies in both online catalogs and bibliographic retrieval systems, focusing on issues of the nature and sources of problems users encounter in each. The goal is to identify common problems and to assess whether they are specific to a type of system or a type of user, or whether the problems are inherent in the information-retrieval task. We propose several research questions and identify areas requiring further research.

Behavioral Factors in Information Retrieval

Online searching of bibliographic-retrieval systems is a complicated process with a multitude of variables. Previous reviews of online searching behavior have attempted to identify and organize some of these variables. Borgman [18,21] focused on psychological variables and Fenichel [47] focused on solutions to interface problems,

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while Eisenberg [42] reviewed issues of end-user searching. Bellardo [10] touched on early user studies, but also reviewed various management issues in online searching. Markey [84] covered subject searching in library catalogs, both card and online. Fidel and Soergel [51], rather than reviewing results, classified hundreds of searching variables into nine categories, five of which are considered in this review: the searcher (the "hands-on" user of the system, whether end user or search intermediary; Fidel and Soergel consider these separately), the search system (features that may contribute to user problems), the search process (the way in which the search is performed, including errors made), and search outcome (recall, precision, and other measures of search success). While the importance of the remaining factors (setting, request, database) cannot be denied, they are outside the scope of the issues presented here.

Nature of Searching Problems

Information retrieval is inherently a complex task. It involves the articulation of an information need, often ambiguous, into precise words and relationships that match the structure of the system (either manual or automated) being searched. In an automated environment, the user must apply two types of knowledge: knowledge of the mechanical aspects of searching (syntax and semantics of entering search terms, structuring a search, and negotiating through the system) and knowledge of the conceptual aspects (the "how and why" of searching—when to use which access point, ways to narrow and broaden search results, alternative search paths, distinguishing between no matches due to a search error and no matches because the item is not in the database, and so on).

Once the mechanical aspects of searching are conquered, one usually can achieve some results from the system. Only when the conceptual aspects are understood can the user exploit the system fully.

Problems with Mechanical Aspects

Bibliographic Retrieval Systems. Problems with the mechanical aspects of searching have not proven to be a major barrier to the use of bibliographic retrieval systems, although several studies have found that they are a barrier for very inexperienced and infrequent users (Lancaster *et al.* [75] Sewell and Bevan [109]). Fenichel [46,48] found that both moderately experienced and very experienced searchers made significantly fewer nontypographical errors per search than did novices, although the overall number of errors was small (2.8 per search for novices).

Penniman [99], in an online monitoring study of the NLM Medline system, found that users had difficulty logging onto the system. Sixty-nine percent of the unique ID numbers were spurious and generated by users attempt-

ing to logon with a mistyped or incorrect ID number. Penniman, defining error only as erasures of some search command or term, found an average of 8% of user actions as errors. Tolle and Hah [119], using the same definition on the NLM Catline database, also found an average error rate of 8%. Other studies of bibliographic retrieval systems either have not found a significant rate of mechanical errors or have not reported error rates at all.

Online Catalogs. Far more problems with the mechanical aspects of searching have been encountered in studies of online catalogs than in studies of other bibliographic retrieval systems.

In 1981–1983, the Council on Library Resources (CLR), funded a nationwide study of online catalogs in public, university, and college libraries, including both in-house-developed systems and commercially-developed systems. In all, 16 different systems in 29 libraries and more than 8,000 users and 4,000 nonusers were studied, using multiple research methods (surveys, online monitoring, focus group interviews, and feature analyses). The survey data are summarized in Matthews *et al.* [90]; a full bibliography of the project can be found in Matthews and Lawrence [89]. Much of our knowledge of online catalog searching comes from these studies. Hildreth [60] provides a concise summary of the searching problems identified in both the survey and monitoring studies of online catalogs done under the CLR studies.

Mechanical problems have been particularly evident in online monitoring studies (Penniman and Dominick [100] and Rice and Borgman [104]). Tolle [117,118], in monitoring studies done as part of the CLR studies, found that errors were not isolated. Instead they tended to occur in clusters; once an error was made, the next transaction was likely to be an error as well. In the Scorpio system of the Library of Congress, given that an error was made, the likelihood that the next command was an error was 59.8%; for the SULIRS system at Syracuse University, it was 28.6%; for the LCS system at the Ohio State University it was 33.3%. Errors were defined in Scorpio as unrecognizable search commands; in SULIRS as an unrecognizable command, an incorrectly formatted command, or an invalid item number; and in LCS as partially or fully unrecognizable commands.

The same data indicate that users tend to quit immediately after receiving an error message. The frequency of moving directly from an error state to ending the session was 8.7% in Scorpio, 5.7% in SULIRS (where moving from an error to a help request was only 0.6%); 10.8% in LCS, 12% at Dallas Public Library (where the overall error was very low, 1.7%, because it is a combination form fill-in and menu system with few defined errors) (Tolle [117]), and 15% in NLM Catline, where errors were defined as erasures (Tolle and Hah [119]).

In a monitoring study of the online catalog in five of the Ohio State University campus libraries, for example, Borgman [16,17] defined two types of errors: logical er-

rors, or commands that could be partially recognized by the system, and typing errors, or commands that could not be recognized at all. Errors were roughly equally divided between the two types. Total errors ranged from a low of 11.2% of all commands in one of six campus locations studied to a high of 15.4% of all commands in another, for an average of 13.3% of all user commands. On average, 12.2% of all user sessions studied consisted entirely of errors.

Dickson [37] and Taylor [115] each analyzed monitoring data from the NOTIS system at Northwestern University. Specifically, they studied search input that resulted in no matches on known-item (author or title) searches. Dickson found that 37% of all title searches and 23% of all author searches resulted in no matches. She determined that 39.5% of the no-match title searches and 51.3% of the no-match author searches were for records that existed in the database and were not found due to user errors in searching. Fifteen percent of the errors in title searches could be attributed to typographical errors or misspellings; the remaining errors were conceptual in nature.

In a different sample of the same data, Taylor [115] found that only 22.4% of the no-match author searches could be determined to be good author names that were not in the database; the remaining 77.6% could have been for records actually in the database. Taylor was able to attribute 22.1% of the no-match author searches to misspelled words.

Conceptual Aspects

Conceptual problems are defined as those that are caused by a lack of understanding of the search process. These may include incorrect use of Boolean logic or truncation, incorrect term structure (swapping surname/first name order, use of initial articles), a failure to modify poor search results, and other factors that result in a failure to locate a substantial portion of the relevant records sought.

Bibliographic Retrieval Systems. While problems with system mechanics are rare for both experienced and inexperienced searchers of bibliographic retrieval systems, many studies have identified significant problems with search strategy and output performance (Fenichel [46-48], Lancaster [74], Lancaster *et al.* [75], and Timbie and Coombs [116]).

Searchers often miss obvious synonyms or fail to pursue strategies likely to be productive (Fenichel [46,48], Martin [88], and Oldroyd and Citroen [98]). Similarly, searchers often fail to take advantage of the interactive capabilities of the system (Fenichel [46,48], Martin [88], Oldroyd and Citroen [98], and Pollitt [103]). Fenichel [46,48] found that in half the searches studied, the initial strategy was not modified; searchers (even experienced ones) tended to use only the most basic techniques of selecting and combining terms.

In a survey comparing searching problems to prior training, Wanger *et al.* [123] found that most respondents said they had difficulty in developing search strategies "some" (47%) or "most" (8%) of the time. Thirty-six percent said they had difficulty in making relevance judgements some of the time.

Perhaps as a consequence of relying primarily on simple search techniques, recall scores are often relatively low, even when comprehensive bibliographies were requested (Fenichel [46,48]). In reviewing studies that computed recall measures, Fenichel [47] shows that average recall ranges from a low of 24% (novices only) to a high of 61%. On expert or mixed subjects, average recall ranged from 41% to 61%. Average precision in the same set of studies ranged from 17% to 81%.

Wanger *et al.* [124], Wanger [122], and Bates [9] note that searchers often fail to consider the inverse relationship between recall and precision in searching, not recognizing that it is necessary to accept a low score on one measure to achieve a higher score on the other.

Online Catalogs. The online catalog studies also have identified many problems with the conceptual aspects of searching, although they have focused more on problems related to misunderstanding of system features than to achieving high levels of performance.

Similar to Fenichel's [46,48] findings, the survey data from the CLR studies (Matthews *et al.* [90]) indicate that online catalog users rarely ventured beyond a minimal set of system features. The majority of searches were simple, specifying only one field or data type to be searched (only about 1/5 to 1/3 of user sessions included more than one search type); the advanced search features (e.g., explicit limit, combine, and term truncation) were rarely used; even when systems included the feature of scanning lists of index terms or headings (similar to the "expand" command in Dialog), users did not utilize the feature unless "forced" to do so. The search success rate was not high; about 1/3 to 1/2 of all searches resulted in no matches (subject searches resulted in no matches more often than did other types of searches).

Survey respondents also indicated that they had problems with several of the conceptual aspects of searching, including increasing search results when too little (or nothing) is retrieved, reducing search results when too much is retrieved, and use of truncation. Users also reported that they experienced a lack of control over the search process and that they found many of the codes and abbreviations in the displays confusing (Matthews *et al.* [90]).

In assessing problems with specific types of searching, the survey found that subject searching was the most problematic area. Users indicated that they had problems both with performing the subject search and with identifying the right subject terms. Markey [84] suggests that because users expressed entry problems only with subject searching, while the form of entry for subject and known item searches is very similar, the problems are due

instead to the conceptual and intellectual aspects of subject searching. In several monitoring studies reviewed by Markey, no-match subject searches range from a low of 35% on Melvyl (Kern-Simirenko [66]) to a high of 57% in the BACS system (Johnson [63]). Across all the systems studied in the CLR project, subject searching was found to constitute the majority (59%) of searches (Matthews *et al.* [90]).

Several of the sources of no-match errors for items actually in the database identified by Dickson [37] were conceptual in nature. Inclusion of initial articles accounted for 10.1% of the no-match title searches, wrong name order (names flipped) accounted for 12.6% of no-match author searches, and the wrong forename or the incorrect inclusion of a middle initial accounted for another 9.9% of the no-match author searches. Taylor [115] found that 16.7% of no-match author searches were due to putting the forename first, another 5.6% were due to the incorrect use of a middle initial, and 5.7% were due to searching title or subject terms in the author field.

Although few quantitative data are available, Hildreth [59] and others have noted that Boolean logic appears to be one of the most difficult aspects of information retrieval. Related research in psychology has shown that Boolean logic is an inherently difficult task and one that is not "common sense" for most people (Tversky and Kahneman [120]). Borgman [19] provides anecdotal evidence on problems with Boolean searching, including using AND in place of OR, and structuring conflicting Boolean statements. Martin *et al.* [87], in an exploratory analysis of search log data on SULIRS, note that users seem unaware of the implicit Boolean AND in the system, typing in full titles or subjects that often result in no matches.

What Have We Learned About the Nature of the Problems?

After reviewing the recent research, we find that people have problems using information-retrieval systems in general, both online catalogs and other retrieval systems, and with both the mechanical and conceptual aspects of searching.

The online catalog studies, which included a large sample of systems and users, consistently found problems with the mechanical aspects of searching. Survey results indicate perceived problems in use, but more telling are the results of the monitoring studies that report significant frequencies of input unidentifiable by the system, aborted sessions, and searches with no matches when the records exist in the database.

In contrast, the mechanical aspects of searching appear to be a problem in other retrieval systems only for infrequent and inexperienced users. More experienced and more frequent users tend to catch mechanical errors and correct them before they cause damage (although

Penniman's [99] findings of logon problems suggests that mechanics remain a problem for many).

Studies of online catalogs are, by their nature, studies of end users, just as studies of bibliographic-retrieval systems are studies of search intermediaries. End users will be low-frequency users, compared to those performing searches for a multitude of clients. Even the low-frequency search intermediaries may be more frequent users than the typical online catalog user. For example, Penniman [99] defined low-frequency users of NLM Medline as 0.5-4.0 hours of use on at least 4 different days, in 5-9 search sessions, over 43 data collection days. Tolle and Hah [119] used the same definition for NLM Catline over 41 data collection days, or about 1-1½ searches per week in both cases. Wanger *et al.* [124] defined low-frequency Medline users as 0-5 searches per month. While no directly comparable figures are available, the CLR survey data (Matthews *et al.* [90, p. 86]) indicate that 68% of respondents used the library at least once a week and that 21% of respondents indicated that they used the online catalog "every visit." These figures suggest that the *high-frequency* users are the 14% (0.68×0.21) who use the online catalog once a week or more. Low-frequency online catalog users are harder to define. Across all types of libraries, 10% of respondents were first-time users of the online catalog (15% at public libraries, 23% at state and federal libraries) (Matthews *et al.* [90, p. 86]). Usage rates are low enough that many online catalog users probably remain "permanent novices."

In comparing the types of conceptual errors encountered in searching online catalogs and other types of retrieval systems, two themes emerge: People have difficulty in understanding how to implement their questions in terms of the system and they have difficulty retrieving substantial proportions of the relevant material existing on a topic.

The bibliographic-retrieval studies have a different focus than the online catalog studies. Here we see little evidence of lower-level conceptual problems such as implementing Boolean logic or understanding the conceptual process behind the command language (although these aspects have received little direct study). Rather, the bibliographic-retrieval studies show deeper problems in making use of the systems' interactive capabilities (which may be due to a lack of understanding of the more sophisticated aspects of searching), designing effective search strategies (including exploring all options available), and achieving high recall from the system.

In online catalogs, we find that users are having problems with the features that provide control over the search. They have difficulty performing subject searches, both in selecting terms and in executing the search, and they have problems both with increasing and decreasing the search result. Boolean logic and index-browsing features may be used incorrectly, if at all. Online catalog users tend to perform simple searches, using only the basic search features, and not taking advantage of the more sophisticated capabilities of the system.

These results suggest that information retrieval is a complex task for users of both types of systems, regardless of degree of experience or type of training. Users seem to have a difficult time defining search strategies and executing them in an optimal manner.

Sources of Problems

Having identified the nature of the problems encountered on various types of retrieval systems, we now consider the research into the sources of those problems. Sources fall into two categories: those due to differences among individual users and those due to specific system features. The individual differences studies pursue the hypothesis that some people find it more difficult to use systems than others; that research attempts to isolate the factors that distinguish the groups. The studies of system features pursue the complementary hypothesis that some systems are easier to use than others. These studies attempt to isolate the factors that distinguish the systems.

Individual Differences

Studies of various technologies, including information-retrieval systems, have found a wide range in people's abilities to use them. Differences among research subjects often overshadow differences among experimental factors (Egan and Gomez [41]).

Egan and Gomez and their colleagues at Bell Laboratories have isolated age and spatial memory ability as key factors in text-editor use (younger people and those with better spatial memory are the best performers) (Egan and Gomez [40,41], Egan *et al.* [39], and Gomez *et al.* [55]). Further studies have shown that spatial memory ability is related to the task of transferring between text on paper and text on the screen and that age is related to task complexity.

Similarly, studies of programming aptitude have found significant correlations between grades in college programming courses and standardized achievement tests (ACT, DAT, SAT), high-school grade-point average (GPA), number of high-school math courses, number of high-school science courses, and college GPA (Alspaugh [1], Butcher and Muth [30], Campbell and McCabe [31], Coombs *et al.* [35], Fowler and Glorfield [52], Konvalina *et al.* [72], Peterson and Howe [102], Simpson [111], Stevens [113], and Stevens *et al.* [114]).

Another set of studies has shown that programmers consistently fall into certain personality types. Sitton and Chmelir [112] and Lyons [81] each tested programmers on the Myers-Briggs Type Indicator (Myers [94] and Myers and Myers [95]). These studies found that programmers tend to cluster into the personality categories with the greatest emphasis on problem solving, logic, and impersonal analysis. Results of such studies on other information technologies leads us to believe that individual

differences are a promising path of study for information retrieval.

Bibliographic-Retrieval Systems. Studies of user behavior on bibliographic-retrieval systems have long found high variance in usage patterns, even when the same system and database are used (Bourne *et al.* [27], Fenichel [46,48], Katzer [65], and Oldroyd & Citroen [98]). In summarizing the characteristics of the "average" search across multiple studies, Fenichel [47] reports broad ranges in reported means for variables such as number of descriptors searched, commands used, connect time, retrieved references, recall, precision, and unit cost. Only recently have researchers begun to identify systematically the sources of some of the variance observed.

Several studies have attempted to identify differences in searching capabilities by degree of experience with the system. Fenichel [46,48] was able only to determine that novices (low experience on the ERIC database and low searching experience) searched more slowly and made more errors than experienced searchers. She found some evidence that searchers who had extensive experience with both the system and the database achieved higher values on the "search effort" variables (e.g., commands used, descriptors searched, and connect time) than searchers who were experienced with the system but not with the database.

Penniman [99] found that frequent searchers of the NLM Medline system used about the same number of single terms and displays in a search as did infrequent searchers, but twice as many advanced-term search entries and half again as many Boolean searches. Moderately frequent searchers used more of all types of commands than infrequent users.

In studying the NLM Catline system, Tolle and Hah [119] found that frequent users were less likely (8% of the time) to end the search immediately after an error (erasure) than were moderately frequent (11%) or infrequent users (20%). The average number of errors ranged from 4% of user inputs for frequent users to 9% for infrequent users.

Experience on other types of systems also may be a factor in information-retrieval performance. Elkerton and Williges [43,44] studied the use of a technical database on an in-house system by users who were classified as either computer naive or computer sophisticated, all of whom were new to the retrieval system. Computer experience was measured by a combination of coursework, daily use of computers, and text-editing knowledge. The researchers found highly significant differences ($p < 0.0001$) between the computer-naive and computer-sophisticated groups on all measures of retrieval performance.

Two recent dissertations (Bellardo [11,12], Woelfl [129]) have explored the personality differences that may underlie searching performance. Bellardo used as her subjects graduate library school students who had just completed a course in online searching. She tested them

on two measures of creativity [the Khatena-Torrance Creative Perception Inventory (Khatena and Torrance [67])], one measure of personality [Interpersonal Disposition Inventory (Berzins et al. [14,15])], and obtained their Graduate Record Exam (GRE) scores. Bellardo attempted to correlate these measures with search performance (precision and recall), but was unable to explain much of the variance. However, she did find a significant ($p < 0.05$) correlation between search performance and GRE quantitative scores, but no correlation with GRE verbal scores.

Woelfl [129] tested skilled NLM Medline searchers on the Learning Style Inventory (Kolb [70,71]) and the Remote Associates Test and the Symbolic Reasoning Test, both part of Guilford's "structure of the intellect" model (Guilford [56] and Guilford and Hoepfner [57]). These measures were correlated with seven variables from four predefined Medline searches: two outcome variables (recall and precision) and five process variables (connect time, number of commands used, cycles completed, descriptors keyed, and number of references printed). Woelfl found that searchers clustered strongly in the "convergent" quadrant (high active, high abstract) on the Learning Style Inventory (LSI), a test based on the personality classification research of Jung [64]. Overall, the cognitive attributes affected search process but not search results. The Symbolic Reasoning Test, one that assesses logical deductive skills, was the only measure related both to search process and search results.

Wanger *et al.* [124] attempted to stratify performance on three variables: type of training (formal, trained by NLM, or informal, all other forms of training), organization type (academic, health-care, or research-related institutions), and frequency of NLM searching (low, 0-5 searches per month, medium, 6-15, high, 16 or more). Although the results indicated high variance in search performance, both in terms of recall and precision, none of the experimental variables explained a significant amount of the variance. It should be noted, however, that the complexity of the variables would result in large variance *within* each group (for example, informal training includes everything from self-instruction to full library-school courses), making it difficult to identify variance *between* groups.

Wanger *et al.* [124] and Woelfl [129], both of whom studied Medline searchers, found significant differences among the search questions tested. Each study found that performance was inconsistent across all search tasks; no group stood out as being best in all cases. The difference in the nature of search questions used across studies makes them difficult to compare and further complicates the assessment of individual differences.

Online Catalogs. As with other types of information-retrieval systems, we find a wide range in skills among online catalog users. Monitoring studies, for example, have identified high variance in the types of searches performed, in the length of searches, and in the patterns of

errors (Borgman [16,17], Larson [77], and Tolle [117]). Each of these were unobtrusive field studies and did not collect any data on individual users that could be compared to the search pattern data. Survey data of the same population found a comparable range of user-reported success and satisfaction levels in system use and a broad range of user background characteristics (Matthews *et al.* [90]).

Matthews and Lawrence [89] (Lawrence and Matthews [78]) reanalysed the CLR survey data in an attempt to identify relationships among the success/satisfaction variables and the user characteristics variables. They found that the most important factors in user-perceived success and satisfaction with online catalog searching were frequency of use of the online catalog, of other catalogs, and of the library itself. That is, the heaviest users of the online catalog and the heaviest users of the library were the most satisfied with the systems. Among the other findings were that those who receive some initial training and assistance in system use are more satisfied than those who do not.

The content of the training also may affect searching ability. Borgman [19,22] compared conceptually based training to procedurally based training, using a "mental models" theory (Gentner and Stevens [54]). As predicted, she found no difference between the training groups on simple search tasks (one or two terms, one index), but those in the conceptually trained condition performed better on complex searching tasks (multiple terms, multiple indexes, or Boolean operators).

Demographic characteristics have been compared in both surveys and a laboratory study. Matthews and Lawrence [89] found that age, sex, and academic status have only an indirect effect on success and satisfaction in that they affect the frequency of library use (although men were heavier online catalog users than women). They did not find relationships between the success/satisfaction variables and prior computer experience, online catalog system, or library.

Borgman [19,22] incorporated demographic characteristics in the study mentioned above, and found that they contributed significantly to the ability to pass a benchmark test of information-retrieval skills after initial training. More than one-fourth of the subjects (in a sample of 43) were unable to pass that benchmark test. The performance difference between those who passed and failed was great ($p < 0.0001$); subjects dropped out equally from both training conditions and subjects of each sex failed in equal proportions.

An analysis of demographic characteristics determined that those who passed the test came from different majors than those who failed. The dropouts were predominantly social science and humanities majors, while those passing the test were science and engineering majors ($p < 0.0001$). Prior computer experience was controlled (subjects had no information-retrieval experience and at most two programming courses).

Based on the above results, Borgman [23] is pursuing the hypothesis that academic major is a gross measure of individual differences and is probably a surrogate for other characteristics that are associated with major. Preliminary results of a study incorporating personality tests used by Woelfl [129] and demographic characteristics identified in studies of programming aptitude indicate that engineering majors cluster strongly around personality characteristics associated with both information retrieval and programming, while English and psychology majors show either no pattern or one opposite that of engineering majors.

Design Problems

It is easy to make a general claim that many of the problems encountered by users are due to design deficiencies, but it is much harder to substantiate such a claim with data. So many variables are involved in the use of interactive systems that it is difficult to isolate individual design features. It does appear that the trend in the emerging field of human-computer interaction is toward controlled studies of individual systems in an attempt to develop theories of both user behavior and systems design (Association for Computing Machinery [4,5], Borman and Curtis [26], Janda [62], and U.S. National Research Council [121]).

One example of the kind of work that can be done is the studies by Roberts and Moran [105,106] in developing a methodology for evaluating text editors based on user performance with a variety of systems. No comparable methodology yet exists for information-retrieval systems.

Bibliographic-Retrieval Systems. Very little evaluative work of commercial information systems has appeared in the open literature; it is possible that such studies are being done on a proprietary basis by their vendors but are not being publicly released. The few system evaluations that appear publicly tend to be management-oriented system comparisons, focusing largely on features that contribute to cost-effective searching (Bement [13], Krichmar [73], Ross [107], and Rouse and Lannom [108]).

One important early work in comparing systems is the features analysis of then-extant information-retrieval systems done by Martin [86]. It is a useful starting point for isolating features to be studied in information systems. Hildreth's [58] later feature analysis of online catalogs follows Martin's initial model.

The only published study identified comparing design features of commercial retrieval systems is by Areu *et al.* [3], who compared the ease of learning Boolean searching on the Dialog and SDC Orbit systems. They compared subjects on each system who were experienced or inexperienced in computing and mathematics. The researchers found significant differences between inexperienced Orbit and inexperienced Dialog groups, and between experienced

Orbit and inexperienced Orbit groups, but no difference between experienced and inexperienced Dialog groups; all differences favored Dialog or the experienced groups. They concluded from these comparisons that "it is easier for an individual with no previous search or programming experience to compose queries using Dialog" (p. 15).

Online Catalogs. The survey studies on online catalog use funded by the Council on Library Resources represent the only studies identified of online catalog design features. Included in the CLR survey were questions about what online catalog features caused problems (Matthews *et al.* [90]). The majority of problems cited were in search formulation and output control, but because the specific system implementation of these features varied greatly across libraries the results tell us more about perceived problems than about specific design features. The researchers do note that features that relieved one problem often created another, especially by adding to the complexity of the interface.

One purpose of the later reanalysis of the survey data was to isolate relationships between problems with specific features and the features implemented in individual systems. Matthews and Lawrence [89] were unable to find significant correlations between specific complaints and individual systems, and found that the problems were surprisingly similar across libraries and systems.

What Have We Learned About the Sources of the Problems?

Although the research on sources of problems in user behavior is at an early stage of development, we are beginning to see some trends in both online catalogs and other information-retrieval systems. The individual-differences research has done more to identify the range of performance and satisfaction than it has in identifying the variables responsible. The degree of variance is perhaps the strongest user behavior finding in information retrieval to date. On any given system, people will search in different ways, with different levels of success and satisfaction. Until we can identify the factors responsible for low success rates, it will be difficult to narrow the performance range, moving users toward the upper end of the success scale and thus removing barriers to access.

In bibliographic retrieval systems, the most important variable determining search patterns and success appears to be experience or frequency of use, but even these results are not strong. Fenichel [46,48] found that database experience in combination with system experience was necessary to achieve better results, and Penniman [99] found that frequent searchers used more of the advanced commands than did infrequent searchers. Experience may have more effect than training, as no direct effects of training have yet been identified on this class of systems. The Wanger *et al.* [124] study compared NLM training to all other forms of training and found no differ-

ences. If the "all other" forms of training had been studied separately, stronger training effects might have been identified. In spite of these findings, we know from research discussed earlier that poor searching occurs at all levels of training and experience.

Similar patterns are occurring in online catalog usage. Frequency of use of the online catalog, other catalogs, and the library were the best predictors of self-expressed search success and satisfaction (Matthews & Lawrence [89]). Matthews and Lawrence also found that those who received some initial training and assistance in system use were more satisfied than those who did not. The survey data showed that the form of training was important, with users preferring print and online training to other forms (Matthews and Lawrence [89]), and experimental data indicated that the content of the training affects search success (Borgman [19,22]), with conceptual training superior to procedural training, at least for complex tasks.

The research across all types of information-retrieval systems suggests that frequent use of a system and a database leads to better use, and some training is better than no training. These results are not yet very strong, but they offer a direction for pursuing relationships among performance, training, and experience.

Studies of demographic variables affecting system use are also at an early stage, but with some intriguing results. Bellardo [11,12] found little substance to the claims that a vast number of personality characteristics were prerequisites for good searching. In contrast, Woelfl [129] found some particular thinking styles common to Medline searchers and that some personality characteristics did correlate with search success.

Mixed results were found on the importance of demographic characteristics. The CLR survey data did not identify any differences in expressed success or satisfaction by such variables as age, sex, education, or academic discipline (Matthews and Lawrence [89]).

In contrast, experimental data found academic major to be an important success-related variable (Borgman [19,22]) and subsequent psychometric testing has shown that major is related to other measures previously shown to be related to information-retrieval aptitude (Borgman [23]). On an in-house system, Elkerton and Williges [43,44] found prior computer experience to be very important in determining success rates, although it was not found to be important by Matthews and Lawrence. It is important to note the contrast in research methods here: The survey data measured *perceived* success or satisfaction (Matthews and Lawrence [89]), while the experimental data measured *actual* success (Borgman [19,22]).

Intuitively it seems that design factors should be important sources of variance in user behavior, but the little research done fails to support such intuition. The inability of Matthews and Lawrence [89] to associate expressed problems to specific design features may be due to the lack of sensitivity of the survey data. Laboratory studies

should be more effective in isolating design features. Hildreth's [58] analysis of online catalogs provides a classification of features for use in designing such research.

While it is not surprising that commercial vendors have not openly published human-factors studies of their systems, we would expect more studies to be done on online catalogs. All of them are in continuing development and human-factors studies are a primary source of data for the types of improvements needed.

Discussion

Research Questions

The research to date on user behavior on bibliographic retrieval systems suggests several conclusions: People have problems searching both online catalogs and other types of retrieval systems, and the problems may be related to individual characteristics and background or to design features. Unfortunately, the existence of problems is more readily confirmed than are the sources of problems.

In assessing the problem areas in user-system interaction, we have made a distinction between knowledge of the mechanical aspects of searching, or the ability to use the system features at a threshold level, and knowledge of the conceptual aspects, or the ability to exploit the system. Mechanics are of concern because they determine whether a user will gain access to the system. Conceptual understanding is of concern because it determines whether the system can be utilized sufficiently to satisfy an information need.

A critical variable in studying both mechanical and conceptual problems in system use is experience or frequency of use. While most studies have referred to experience and frequency of use synonymously, it may be more constructive to consider them as separate variables. Experience may be defined as the length of time of use (e.g., months, years) and frequency defined by the amount of time between sessions with the system. We may find that the effect of a given number of online sessions may be time dependent; that is, the user who has interacted with a system ten times over a period of two years may have different skills (and different problems) than the user who has interacted with it ten times over two weeks.

Another way to view the frequency/experience variables is in terms of interaction with the type of system. When considering these factors as a matrix (Figure 1), we find that the vast majority of work has been in two of the four cells. We know much about search intermediaries using commercial retrieval systems and much about library patrons (end users) on online catalogs, but not much about the other combinations. We need to study the other cells if we are to determine the true interactions between experience/frequency of use and system type.

	High experience	Low Experience
Information Retrieval Systems	WELL-STUDIED Search Intermediaries	LITTLE STUDY End Users
Online Catalog Systems	LITTLE STUDY Librarians & Skilled Users	WELL-STUDIED Library Patrons

FIG. 1.

The low experience/information retrieval systems cell can be filled by studies of the end-user-oriented systems, such as Dialog's Knowledge Index or BRS/After Dark. Studies of The Source and CompuServe also may be helpful here. A few studies of these users have been done, but most deal with the introduction of services (management issues) or marketing issues (e.g., Evans and Pisciotta [45], Lescohier et al. [79], Lyon [80], Kirby and Miller [68], and Klausmeier [69]).

We can fill the high-experience/online catalog cell by studying reference librarians and library technical services staff who use these systems daily, both as search intermediaries and for their own use. Some library patrons fall into this category, but they are harder to identify as research subjects than are library staff.

Research in the high-use category is especially valuable for characterizing task expertise. Research in other domains has compared expert to novice behavior on a specific task such as analyzing circuit diagrams (e.g., Geiselman *et al.* [53]). The purpose of such research is to identify the important components of the task and the critical decision points such that the skills of experts can be taught to novices. By studying skilled searchers, as Bates [7,8] and Fidel [49,50] have done on bibliographic retrieval systems, we can learn the necessary searching components to teach to novices.

In addition to studying experience variables, we need to study the individual-differences variables and system features that may be contributing to user problems. For problems with the mechanical aspects of searching, research questions in all of these areas could be addressed by a series of controlled studies, both in the laboratory and in the field. It would be necessary to collect data from multiple systems, closely matched for implementation of specific features hypothesized to be problematic. We would need to collect demographic and personality data to control individual-differences variables and apply mul-

iple training methods (including no training) to compare training effects. Any study would have to continue for a sufficient length of time to test experience effects (as distinct from frequency of use). In general, the training variables and individual-differences variables are probably best studied in the laboratory, while the experience/frequency variables are probably best studied in the field.

The conceptual problems in user-system behavior are of even more concern than the mechanical problems. As systems evolve, they (theoretically) become easier to use and people become more familiar with them, leading to a decrease in mechanical errors. Bibliographic-retrieval systems have evolved to the point that the mechanical aspects appear to be a problem only for the inexperienced or infrequent users; online catalogs may not have evolved to this point or perhaps the frequency of use is below some minimum threshold which has been reached on the other systems. Another explanation is that some fundamental difference exists in the user population or task that has not yet been identified.

Even with the heavily used bibliographic-retrieval systems that have been evolving for two decades, conceptual structure remains a problem for searchers. Performance, both in terms of use of system features and in terms of output measures, remains poor even for experienced searchers. We have less data on performance measures for online catalogs, but the high failure rate of searches for items investigators have shown to be in the database suggests that performance on online catalogs is no more satisfactory than that of other bibliographic retrieval systems.

We are led to several research issues surrounding the nature of the conceptual problems. We must ask if information retrieval is so inherently difficult that supporting the intellectual task is not fully within the state of the art of computing. Or are the problems related to the nature of the question, with some questions beyond the capabili-

ties of present-generation systems? If so, how can we distinguish between "searchable" and "unsearchable" questions? What capabilities should be added to support these "unsearchable" queries?

We also must ask if the factors determining search success (based on a conceptual understanding of the system and the search process) are within direct control—training and design—or only indirect control—variance in individual characteristics. If the factors are based on training or design, we can isolate them and make improvements accordingly. If the factors are based on individual differences, it still may be possible to isolate the effects of the most important sources of variance and adjust the training or design accordingly.

The research questions on conceptual problems are complex and will require a long program of research. We need to collect data on multiple systems, in multiple environments, both in the laboratory and in the field. It will be necessary to test subjects to determine individual differences (after preliminary research to identify fruitful variables for study). To identify the effects of experience, some longitudinal data will be needed—following subjects through their undergraduate years, for example. We will need to experiment with types of training methods, both by designing training programs based on promising pedagogical techniques and by comparing the performance of users trained by standard sources.

Few of the user-system behavior issues found in information retrieval are likely to be confined to that technology. Various mechanical and conceptual problems have been identified elsewhere (text processing is the best studied) that may be relevant to information-retrieval problems. Just as studies of bibliographic retrieval systems are valuable to the study of online catalogs, studies of text processing and other information technologies may be valuable to the study of all types of retrieval systems.

One promising indication of research progress is the series of conferences (and associated proceedings) organized by the Council on Library Resources to bring together people within the field of library and information science to address specific issues in online catalog design. Among the conferences to date have been one on training issues (McClintock [91]), one on general design issues (Aveney [6]), one on command languages (Peters [101]), and one on screen displays (Williams [125]). The conferences have brought together designers and experts in related areas to discuss problems, potential standards, and questions for future research. Among the recommendations of the screen design conference was the funding of research to bring existing human factors knowledge to bear on online catalog screen design. Such work is sorely needed and the Council's efforts are a positive step toward accomplishing the research.

Interim Solutions

In conjunction with ongoing research on users, contin-

uing research and development in systems is necessary. We cannot wait until all the user results are in before continuing with the design process. Rather, it is an iterative process of study, design, test, and redesign.

Among the greatest areas of immediate need is training. We know that people who receive some training in online catalog use report higher rates of success and satisfaction (Matthews and Lawrence [89]), but we also know that users are disinclined to seek training or even to read available documentation.

The CLR survey data (Matthews *et al.* [90]) shed some light on the lack of motivation to seek training. Nonusers of online catalogs were asked *why* they were nonusers; the most common response was that they had not had time to learn. When asked their perception of the amount of time required to use an online catalog, most (64%) estimated 30 minutes or less. Given the complexity of the information-retrieval process and the 10–16 weeks often devoted to teaching online searching in library schools, 30 minutes seems like an unreasonably low expectation, yet it is more than many are willing to invest.

We need to experiment with ways of making training more palatable, both online and offline. It may be necessary to make systems more self-instructional, either through embedding computer-assisted instruction or other user-feedback techniques in systems or by setting up offline training simulators that would alleviate some of the systems load.

Standardization of command languages and screen displays is another way to alleviate some of the problems, at least for users of multiple systems, provided that standardization does not interfere unduly with innovation (Atherton [2] and Cochrane [34]). The European community has already established guidelines for a common command language for retrieval systems (Negus [97]) and the U.S. community has established a working standards group for similar purposes (International Organization for Standardization [61] and National Information Standards Organization [96]). The issues of standards, guidelines and compatibility are very complex, however, and may not be easily accomplished (Lancaster and Smith [76]).

Some problems may be eased through better error-correction algorithms. Taylor [115] found that due to the high frequency of users entering author names in reverse order, 21.7% of no-match author searches could be eliminated with a routine that would automatically "flip" the first and second author names when no matches were achieved on the first search. A second program to search the first word of the author name (as entered) followed by the first letter of the second word (truncated) would retrieve on an additional 18.3% of author no-match searches. Other techniques likely to decrease error rates are to search unmatched terms in the appropriate index, displaying alphabetically adjacent terms, to pass unmatched terms (other than author names) against a spelling check routine, and to force users into a help routine

after one or more identifiable errors. The CITE system has incorporated several such error-correction techniques with success (Doszkocs [38] and Siegel et al. [110]). Error-correction techniques deserve further empirical investigation to determine the amount of relief provided and the cost factors involved.

Another potential solution to access and training problems is the "front end" or "automated intermediary" to information systems that operate on microcomputers with communications capabilities (e.g., Sci-Mate, In-Search, Search Master). A number of commercial front ends have been developed and are currently being marketed for use with information-retrieval systems. They have several purposes and capabilities: They simplify the interface by providing automatic logon procedures and may include a simpler interface (e.g., a menu-driven interface to a command-driven system), help or user assistance may be provided, they may standardize access by providing a common interface to multiple systems, and they may provide additional capabilities, such as downloading and postprocessing. Training, per se, is rarely part of these packages, however.

At present, most of these front ends do more to ease the mechanical than the conceptual problems of use. They alleviate the need for memorizing multiple command languages and provide support for syntax and semantics, but the user still must understand the nature of the search process and the basic capabilities available. Few of the negotiation skills provided by human intermediaries are part of the microcomputer-based front-end systems. The experimental front ends mounted on mainframe computers such as CONIT (Marcus and Reintjes [82,83]) or IIDA (Meadow et al. [92,93]) are more sophisticated and provide more negotiation capabilities. As we learn more about the technology and as the cost of local processing continues to decrease, it may be possible to add more capabilities to the microbased systems.

Microcomputer-based front ends are much less expensive to build than are mainframe retrieval systems, and they are easier to modify. As a result, front ends have the potential of providing tailored interfaces to retrieval systems. One system might have multiple front ends on it, each supporting a user group with different amounts of expertise, experience, or varying personal characteristics. Front ends also can incorporate initial training, refresher training for infrequent users, and assistance throughout the search process. In this way, it may be possible to overcome some of the problems caused by the wide variance in users on one system. In testing the potential of customized front ends, Borgman et al. [24,25] and Case et al. [32,33] have constructed an experimental prototype front end to the Department of Energy RECON retrieval system tailored to the needs of energy researchers. Results of evaluation studies suggest that end users can learn basic search concepts very quickly and that they are enthusiastic about the use of such assistance.

Conclusions

We have found that the users of online catalogs and information-retrieval systems encounter the same problems in usage and that many of the same factors underlie their behavior. Information-retrieval behavior appears to be determined by a number of factors, including training, experience, system features, the nature of the search topic, and individual characteristics. We do not yet have sufficient knowledge of user behavior to make major improvements in systems design and training, yet we know enough to formulate the research questions that may lead to such improvements. As work progresses on these research questions, we gradually will move toward the ultimate goal of making information-retrieval systems accessible for all who choose to use them.

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