CHRISTINE L. BORGMAN
Graduate School of Library and Information Science
University of California—Los Angeles

Toward a Definition of User Friendly: A Psychological Perspective

Introduction

"User friendly" is one of those valuable concepts that has become such an overworked phrase that it has lost much of its meaning. As Meads notes, "[t]he forced grin of user friendliness becomes a mask for lack of capability, insufficient performance, costly maintenance, or a collection of mis-fitting components."[1] User friendly is not merely the addition of high tech hardware such as a mouse, icons, or three-dimensional graphics.

What does *user friendly* mean? First, consider a dictionary definition. Webster's defines *user* simply as "one who uses."[2] *Friendly* is defined as "of, relating to, or befitting a friend: as *a*: showing kindly interest and goodwill *b*: not hostile *c*: inclined to favor *d*: comforting, cheerful."[3] We infer that "user friendly" suggests an entity that is warm and comforting to the one who uses it.

Matthews and Williams defined a "user friendly index" for information systems as a nine-point scale, ranging from "user intimate" at the top to "user vicious" at the bottom, with "user oriented" as a midpoint.[4] They have followed the same line as Webster's, considering "user friendly" as being kind—or at least the inverse of hostile—to the one who uses.

Meads takes the definition of user friendly further by stating three requirements. The first is that the system is *cooperative*—it provides active assistance during the task and makes its actions clear and obvious. Second, the user friendly system is *preventive*—it acknowledges that people make mistakes by preventing those mistakes to the extent possible and by providing backout and recovery procedures. Third, the friendly system is *conducive*—it is reliable, predictable, and assists rather than controls the user.[5]

Meads's three requirements can be combined into the one attribute transparency, a commonly used term from computer science. If a system is transparent to the user, it means that the user is looking through the system to the task being accomplished and not focusing on the system itself. A transparent system is one that supports and simplifies a task rather than becoming a task in and of itself. This paper will discuss current research on information systems that has the implicit goal of making systems more user friendly and that is being conducted from a psychological perspective.

The Human as a Unit of Analysis

The interaction of humans with computers can be studied at multiple levels of analysis. Here we are concerned with the psychology of the user, which is roughly a mid level unit of analysis. By psychology we mean the study of human behavior—i.e., mental and behavioral characteristics as they apply to the use of computers. The research done in the area is largely based on the theories of cognitive psychology. Studies are of the individual user as representing the larger body of users.

Human-computer interaction can be studied at both lower and higher levels of analysis than that of the individual user. At a lower level would be the human factors studies that focus on anthropomorphic dimensions of the human: fitting the keyboard size and layout to the average human hand, designing workstations with the proper dimensions for human comfort, screen displays that minimize glare and eyestrain, and so on.

At a higher level of analysis than the individual is the study of the organization or the social group response to the use of computers. The way in which people use computers is affected by the way in which the systems are introduced, their motivation to use them, the training provided, the threats to the current job, and changes in task and work structure.

All of these levels must be studied to provide a full picture of human use of computers and hence of friendliness. However, they cannot all be studied at once. In this paper we confine ourselves to the study of the individual user.

A Psychological Perspective

Researchers in academic departments of psychology, communication, computer science, and library and information science, as well as industrial researchers, have been applying both psychological theory and method to the study of human interaction with computers. In addition, psychologists have used the study of human behavior with interactive systems as a test-bed for developing theory and method.

The remainder of the paper will cover two distinct bodies of research. First we cover psychological theories that have been applied directly to interactive computer systems. Some theories already have been applied to information systems; others are better proven elsewhere but have potential for use in this domain.

The second body of research to be addressed is studies done to characterize behavior on information retrieval systems—both online catalogs and bibliographic retrieval systems—that is not driven by theory. Rather, it is pretheoretical, gathering data that may lead to theory development later. This body of research utilizes research methods drawn from psychology and other social sciences. We will focus specifically on studies of error behavior because errors interfere with usage and hence with transparency.

APPLICATIONS OF PSYCHOLOGICAL THEORY

Three theories will be considered here, each of which is general and has been applied to other information technologies. The first is that of mental models, an attempt to describe the learning and problem-solving processes involved in the use of computer systems. Second is that of information processing models, an attempt to build discrete quantitative models of interactive behavior. The third theory considered is individual differences, an attempt to explain variance in performance and interaction style by personality and demographic characteristics.

Mental Models

The mental models theory, drawn from cognitive psychology, is perhaps the most appealing theory for the study of human behavior on information systems.[6] Although it has not yet been applied widely to retrieval systems, the research to date holds considerable promise for both design and training.

Psychological Research on Mental Models

Research in learning theory in various contexts has shown that people tend to build hypotheses as part of problem solving. When a person approaches a new task, whether it's fixing a toaster or a carburetor, solving a math problem, or learning a text editor, he or she tends to gather information from the context of the task. The information might be drawn from a manual, from watching other people, from prior knowledge, or from the response of the problem to the user's actions. As the user/problem solver takes an action—such as turning a screw, writing an equation, or entering a command—the problem changes and the result is observed. From all of these sources the user makes further hypotheses about how the entity or problem works and about why it is responding in a particular way. Evidence from actions is taken as supporting or negating the hypotheses made and the hypotheses are refined accordingly with the user taking more actions until the task is completed or abandoned.

All these hypotheses and actions fit together into a "mental model" of how the entity works. The mental model starts out fuzzy and becomes more clearly defined with experience. It is important to note that the user/problem solver is not necessarily aware that he or she has or is applying such a model. The model is part of the problem-solving process and usually is not a conscious effort.

The ability to develop a mental model is a valuable intellectual skill and one that is very helpful when the information applied to the problem is correct and when the hypotheses are correctly interpreted or revised. Unfortunately this is not always the case. A person may not gather enough information about the task first (read the instructions, assess the nature of the problem), or he or she may start with incorrect assumptions such as that it works like some other entity previously seen or that the problem is something other than it actually is. For example, people often assume that a text editor works much more like a typewriter than it actually does or that an online catalog is more like a card catalog than is actually the case. To complicate life further, people often interpret the results of their actions as supporting their hypotheses whether or not they do indeed.[7]

The theory suggests that people can be trained with a conceptual model of the system from which they can draw a mental model that is compatible with their own thinking processes. The research design typically applied in mental models studies is to assign subjects to two groups, one trained with a conceptual model of the system and one trained with a procedural set of instructions (no framework; just "first do this, then do this...."). The underlying hypothesis is that those trained with a conceptual model will develop a mental model and will perform better on the tasks, and those trained only with procedures either will develop an incorrect model or will not develop a model at all.

A further hypothesis is that having a mental model is not as important for the simple tasks that can be accomplished with one or two predefined procedures as it is for more complex tasks that involve multiple procedures or extrapolation from basic procedures.[8]

Applications to Information Systems

The first study to test the mental models theory on retrieval systems compared the two training methods on a Boolean-logic-based online catalog of OCLC records.[9] As predicted, it was found that on simple tasks there was no difference in performance (number of items correct) based on training, but on complex tasks, those trained with a conceptual model of the system got more items correct and exhibited different patterns of interaction with the system than those trained procedurally.

The only other study of mental models and information systems identified to date is a master's thesis from the University of Chicago done by Jean Dickson.[10] Her study was not experimental; rather, she attempted to infer a mental model from the monitoring record of user behavior on NOTIS, the online catalog at Northwestern University. Dickson looked specifically at the errors in author and title searches that resulted in no hits and concluded that users applied different mental models from those applied to a card catalog because they searched differently. Her most striking examples were the frequency of errors due to entering authors with given name first (12.6 percent of no-hit author searches) and due to the inclusion of initial articles in title searches (10.1 percent of no-match title searches), neither of which would be appropriate behavior in a card catalog. Other explanations exist for these behaviors, but the data do suggest that users make incorrect hypotheses about the system.

Information Processing Models

Psychological Research on Information Processing Models

An information processing model is an attempt to break down human tasks into discrete physical and cognitive actions and to assign probabilities of occurrence and performance times to these actions. The model allows task behavior to be calculated and predicted. The computed performance times and patterns can be used to compare methods of performing a given task. The best known of these models are the GOMS (Goals, Operators, Methods, and Selection rules) and keystroke models of Card, Moran, and Newell.[11] The GOMS model predicts human behavior on a specific task in terms of the user's goals, operators, methods, and selection rules. The model was developed using manuscript editing tasks. In this context, Card and his colleagues have achieved roughly 90 percent accuracy in predicting behavior sequences and 33 percent accuracy in predicting time required for modifications.

The keystroke model is more discrete and predicts time to perform a given task as a linear sum of four physical and one mental operators. In text-editing tests, Card's research team modeled behavior with a 21 percent error rate.

These models are useful for comparing features for implementation in designing a system. They have been used for comparisons such as determining whether a control character sequence is better for an editing function than a function key or whether a mouse is better than a joystick for pointing to objects on a screen.[12]

The information processing models on a task are built by training people until they are expert which may take thousands of repetitions. It has been reasonably successful in developing text editing systems which are well-suited to expert, highly repetitive behavior. The models also are being used to advance the information processing theories of cognitive psychology.

Applications to Information Systems

The information processing models have not yet been applied to the design of information retrieval systems. They may be helpful for determining the best use of command sequences in terms of making frequently used actions most accessible, minimizing confusion among actions, and so on.

Overall, the information processing models are less applicable to information retrieval systems than to text editing because the task does not lend itself as well to expert behavior. The information retrieval task is much less clearly defined, requiring heuristic thinking and continual reevaluation of the task. Further, few users of information retrieval systems use them in a production, expert mode. The vast majority use the systems too infrequently to achieve the expert behavior on which the information processing models are based.

Individual Differences

Psychological Research in Individual Differences

Most of the psychological research on human interaction with interactive systems comes from the area of cognitive psychology which is based on the "information processing model" paradigm alluded to earlier. The theory which underlies much of current cognitive research attempts to reduce human behavior to information inputs, processes, and outputs. The intent is to identify fundamental characteristics across all people that can be used to predict behavior. The information processing theorists do not acknowledge differences among people. Rather, they treat such differences as "random variance."

Another branch of psychology is specifically interested in that "random variance." Those in the area of "correlational" or "differential" psychology look for variance in behavior that occurs naturally and then seek factors that differentiate among individuals or groups. Their intent is to identify causal, or at least associative, relationships after the fact.

The differential psychology researchers have determined that some people have an easier time using information technologies than others—including information retrieval systems, text editors, and programming languages. Once the fact has been established that a range of behavior exists, the method is to analyze the behavior of a group of people on the task, capturing data on as many related factors as are hypothesized to be responsible for the differences.

In text editing studies, researchers have found that age and spatial memory are important factors.[13] Those who are younger and who have the best spatial memory capabilities perform best on text editors.

Similarly, researchers have found consistent variance in those who are professional programmers, finding that they fall into a consistent style of processing—more thinking than feeling, more intuitive than sensing.[14] Those who perform best in introductory programming courses also take more science and math courses, score better on general achievement tests (math and verbal), and get higher grades.[15]

Applications to Information Systems

Studies of user behavior on both bibliographic retrieval systems and online catalogs long have found wide variance in usage patterns even when the same system and database are used.[16] In summarizing the characteristics of the "average" search across multiple studies, Fenichel 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.[17] Only recently have researchers begun to identify systematically the sources of some of the variance observed.

Amount of experience with the system is the variable most commonly studied in identifying performance differences. Fenichel was able to determine only that novices (low database experience and low searching experience) searched more slowly and made more errors than experienced searchers.[18]

Penniman, in monitoring studies, 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.[19] Moderately frequent searchers used more of all types of commands than infrequent users.

Three dissertations have explored the personality differences that may underlie searching performance on bibliographic retrieval systems. Brindle studied the relationship between cognitive style and search performance in a field experiment but found few significant differences.[20] Bellardo studied graduate library school students who had just completed a course in online searching, testing them on two measures of creativity and one measure of personality 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 ($p < .05$) correlation between search performance and GRE quantitative scores but no correlation with GRE verbal scores.[21]

In a field experiment, Woelfl tested skilled NLM Medline searchers on inductive and deductive reasoning and learning style. Woelfl found that searchers clustered strongly in one learning style (high active, high abstract). Overall, the cognitive attributes affected the search process but not search results.[22]

As with other types of information retrieval systems, we find a wide range in skills among online catalog users. Monitoring studies have identified high variance in the types of searches performed, in the length of searches, and in the patterns of errors.[23] 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.[24]

Borgman found significant differences in the ability to pass a benchmark test of information retrieval skills by academic major. Those who failed the test 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).[25]

Based on the earlier discussed results, Borgman 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.[26] Preliminary results of a study incorporating personality tests used by Woelfl 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.[27]

ERROR BEHAVIOR

The study of error behavior is crucial to the issues of system transparency. If a system is transparent, it will support and simplify a task—not become a task in itself—and be congruent with the user's thinking style and workflow. The difficulty is in measuring these indicators of transparency. We find usually that it is easier to gather evidence on when a system is *not* working well than on when it *is*. Thus, we study user errors and problems.

User errors and problems with information retrieval systems can be divided into two categories: those encountered with the mechanical aspects of searching (typos, incorrect commands, etc.) and those with the conceptual aspects (controlling the interaction, achieving useful results, etc.).

By identifying errors in the mechanical aspects, we can identify poorly engineered system factors that may be increasing the likelihood of certain types of errors. Identifying the most common errors can lead to isolating nonintuitive command sequences, misleading displays, and other unfriendly aspects of a system.

Similarly, by identifying poor levels of searching performance (low recall and precision, inefficient use of commands, etc.), we can determine ways in which the system interferes with the natural flow of problem solving (retrieving information) and the points at which it fails to be congruent with thinking style and workflow. It also allows us to identify misconceptions about the systems thereby understanding better how people are interpreting system actions and internalizing them into their behavior. With such knowledge both the design of systems and training for them can be improved.

The causes of the errors and problems identified by studying user behavior can only be inferred, of course. But the evidence will result in hypotheses about the sources of the behavior that can be taken to the laboratory for further study.

The discussion here is intended to provide only an introduction to the kinds of studies that can be done to identify user problems with systems. For a fuller discussion of these results and their implications, the reader is referred to Borgman[28] (the applications of psychological theory are discussed at length in another paper by Borgman[29]).

Problems with Mechanical Aspects of Searching

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.[30] Fenichel, in an experiment capturing printed search protocols, 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).[31]

Defining errors only as erasures, Penniman found an average of 8 percent of user actions as errors.[32] Tolle and Hah, using the same definition in a monitoring study of the NLM CATLINE database, also found an average error rate of 8 percent.[33]

Online Catalogs

Mechanical problems have been particularly evident in monitoring studies of online catalogs. Tolle found that errors were not isolated.[34] 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 percent; for the SULIRS system at Syracuse University, it was 28.6 percent; for the LCS system at the Ohio State University it was 33.3 percent. Errors were defined in SCORPIO as unrecognizable search commands; in SULIRS as an unrecognizable command, an incorrectly formatted command, or an invalid item number; in LCS as partially or fully unrecognizable commands. Data from these studies also indicate that users tend to quit immediately after receiving an error message.

In a monitoring study of the Ohio State University (LCS) online catalog, Borgman defined two types of errors: logical errors 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 averaged 13.3 percent of all user commands; 12.2 percent of all user sessions studied consisted entirely of errors.[35]

Dickson[36] and Taylor[37] analyzed the monitoring record of search input on the NOTIS system that resulted in no matches on known-item searches. Dickson found that 37 percent of all title searches and 23 percent of all author searches resulted in no matches. She determined that 39.5 percent of the no-match title searches and 51.3 percent of the no-match author searches were for records that existed in the database and were not found due to user errors in searching. Of the errors in title searches, 15 percent could be attributed to typos or misspellings; the remaining errors were conceptual in nature.

Taylor found that only 22.4 percent of the no-match author searches could be determined to be good author names that were not in the database; the remaining 77.6 percent could have been for records actually in the database. She was able to attribute 22.1 percent of the no-match author searches to misspelled words.[38]

Conceptual Aspects of Searching

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.[39] Experiments using transcripts of search behavior have shown that searchers often miss obvious synonyms or fail to pursue strategies likely to be productive.[40] Similarly, searchers often fail to take advantage of the interactive capabilities of the system.

In a survey comparing searching problems to prior training, Wanger et al. found that most respondents said they had difficulty in developing search strategies "some" (47 percent) or "most" (8 percent) of the time and 36 percent said they had difficulty in making relevance judgments "some" of the time.[41]

Perhaps as a consequence of relying primarily on simple search techniques, recall scores are often relatively low even when comprehensive bibliographies were requested.[42] In reviewing studies that computed recall measures (using a variety of research methods), Fenichel shows that average recall ranges from a low of 24 percent (novices only; 41 percent average minimum recall in other cases) to a high of 61 percent. Average precision in the same set of studies ranged from 17 percent to 81 percent.[43]

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 findings,[44] survey data 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; the advanced search features were rarely used; even when systems included the feature of scanning lists of index terms or headings, users didn't utilize the feature unless "forced" to do so.[45]

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 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.[46]

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. In several monitoring studies reviewed by Markey,[47] no-match subject searches range from a low of 35 percent on MELVYL[48] to a high of 57 percent in the BACS system.[49]

In the monitoring study conducted by Dickson, no-match searches could be attributed to misunderstanding the search structure, such as inclusion of initial articles (10.1 percent of no-match title searches), wrong name order (12.6 percent of no-match author searches), and the wrong forename or the incorrect inclusion of a middle initial (9.9 percent of the no-match author searches).[50] Taylor found that 16.7 percent of no-match author searches were due to putting the forename first, another 5.6 percent to the incorrect use of a middle initial, and 5.7 percent were due to searching title or subject terms in the author field.[51]

CONCLUSIONS

We have discussed the applications of psychological theory to the design of information systems—including mental models, information processing models, and individual differences—and studies of error behavior on both bibliographic retrieval systems and online catalogs. What does all of this imply for making systems more user friendly or transparent?

Implications of Psychological Theory

The results of the mental models research suggest that systems are easiest to use when they are designed around a consistent conceptual model that is readily recognizable by the user. Further, the training and instructions for the system should reinforce the model. Status indicators on the display should indicate the current location in the system, the immediately previous location, and options for the next location. All of these data are helpful in providing a comfortable framework for system use. A transparent system, in terms of a mental model, is one whose conceptual framework is readily adopted by the user, making the system simply a tool to support the task and not a task in itself.

The information processing models have less direct implications for user friendly systems design. They suggest that user actions can be quantified into a string of additive variables, including reaction time, keystroke time, and mental processing time. Therefore, through system evaluation and basic research, we should continue to seek some underlying fundamental characteristics of information retrieval behavior. The practical results of information processing models' research probably are further away from implementation than are the results of other research paths.

The individual differences research suggests is that different people approach systems in different ways, learn at different rates, and prefer different types of training and interfaces. The first step in implementing the results of individual differences research is to acknowledge that the differences exist. When user populations are small or otherwise well-defined, it may be possible to identify common characteristics (e.g., computing knowledge, retrieval knowledge, subject expertise) and tailor systems accordingly.[52] When user populations are diverse and ill-defined (as is the case with most populations of public and academic library clientele), individual differences can be acknowledged by providing multiple forms of interfaces (e.g., menu and command) and by offering multiple forms of training (e.g., classroom training, computer-assisted instruction, printed materials). The provision of options such as these, while not allowing precise tailoring to each individual, does allow users to make choices among the interface styles and training methods with which they are most comfortable.

Error Behavior and Transparency

A review of the research on error behavior suggests that users have problems with both the mechanical and the conceptual aspects of searching information retrieval systems and that the problems occur on both bibliographic retrieval systems and online catalogs. We are beginning to identify some of the problematic factors, although they vary by system. We do know that subject searching tends to be the most problematic type of search in most systems, however, and a candidate for closer study. Another common factor is the tendency to utilize only a subset of commands, not taking advantage of the more sophisticated searching features. We need to determine if the higher-level commands are not taught adequately, are difficult to implement, or are simply unnecessary for most users. Most of all, the results of error-behavior studies suggest the need for continual evaluation of systems so that the problems can be identified and the systems improved.

Future Research

Information systems have not yet reached the stage of being user friendly for most of their users. We now know enough to begin to characterize the problems; much more work is required to find solutions for them. We need both design guidelines to alleviate known problems and basic research to identify general principles of user behavior. The initial groundwork for a psychology of human-computer behavior has been laid and research methods exist to continue the work. A base of implemented systems, available to a variety of user populations, exists for study. With sufficient devotion to research, we may soon have a class of "user friendly retrieval systems."

REFERENCES

1. Meads, Jon A. "Friendly or Frivolous?" *Datamation* 31(1 April 1985):96-100.
2. *Webster's Ninth New Collegiate Dictionary*, s.v. "user."

3. ________, s.v. "friendly."

4. Matthews, Joseph R., and Williams, Joan Frye. "The User Friendly Index: A New Tool." *Online* 8(no. 3, 1984):31-35.

5. Meads, "Friendly or Frivolous?"

6. Gentner, Dedre, and Stevens, Albert L., eds. *Mental Models*. Hillsdale, N.J.: Erlbaum, 1983.

7. Lewis, C., and Mack, R. "Learning to Use a Text Processing System: Evidence from 'Thinking Aloud Protocols.' " *Proceedings of the Human Factors in Computer Systems Conference* (Gaithersburg, Md., 15-17 March 1982). New York: Association for Computing Machinery, 1982.

8. Halasz, Frank. "Mental Models and Problem Solving Using a Calculator." Ph.D. diss., Stanford University, 1984.

9. Borgman, Christine L. "The User's Mental Model of an Information Retrieval System: Effects on Performance." Ph.D. diss., Stanford University, 1984; and ________. "The User's Mental Model of an Information Retrieval System: An Experiment on a Prototype Online Catalog." *International Journal of Man-Machine Studies* 24(no. 1, 1986):47-64.

10. Dickson, Jean. "An Analysis of User Errors in Searching an Online Catalog." *Cataloging & Classification Quarterly* 4(no. 3, 1984):19-38.

11. Card, Stuart K., et al. *The Psychology of Human-Computer Interaction*. Hillsdale, N.J.: Erlbaum, 1983.

12. ________. "Evaluation of Mouse, Rate-Controlled Isometric Joystick, Step Keys, and Text Keys for Text Selection on a CRT." *Ergonomics* 21(1978):601-13; and ________, *The Psychology of Human-Computer Interaction*.

13. Egan, Dennis E., and Gomez, Louis M. "Assaying, Isolating and Accommodating Individual Differences in Learning a Complex Skill." In *Individual Differences in Cognition*, vol. 2, edited by R.F. Dillon. New York: Academic Press, 1985.

14. Sitton, S., and Chmelir, G. "The Intuitive Computer Programmer." *Datamation* 30(no. 16, 1984):137-40; and Lyons, M.L. "The DP Psyche." *Datamation* 31(no. 16, 1985):103-10.

15. Alspaugh, C.A. "Identification of Some Components of Computer Programming Aptitude." *Journal for Research in Mathematics Education* 3(no. 2, 1972):89-98; Butcher, D.F., and Muth, W.A. "Predicting Performance in an Introductory Computer Science Course." *Communications of the Association for Computing Machinery* 28(no. 3, 1985):263-68; Coombs, M.J., et al. "Learning a First Computer Language: Strategies for Making Sense." *International Journal of Man-Machine Studies* 16(no. 4, 1982):449-86; Fowler, G.C., and Glorfield, L.W. "Predicting Aptitude in Introductory Computing: A Classification Model." *Association for Educational Data Systems Journal* 14(no. 2, 1981):96-109; Stevens, D.J. "Cognitive Processes and Success of Students in Instructional Computer Courses." *Association for Educational Data Systems Journal* 16(no. 4, 1983):228-33; and Stevens, D.J., et al. "Group Differences in Computer Science Aptitude." *Association for Educational Data Systems Journal* 14(no. 2, 1981):84-95.

16. Bourne, Charles P. *Analysis of ERIC On-Line File Searching Procedures and Guidelines for Searching*. Berkeley: University of California, Institute of Library Research, 1974; Fenichel, Carol Hansen. "Online Information Retrieval: Identification of Measures that Discriminate Among Users with Different Levels and Types of Experience." Ph.D. diss., Drexel University, 1979; Fenichel, Carol Hansen. "Online Searching: Measures that Discriminate Among Users with Different Types of Experience." *JASIS* 32(no. 1, 1981):23-32; and Oldroyd, B.K., and Citroen, C.L. "Study of Strategies Used in On-Line Searching." *On-Line Review* 1(no. 4, 1977):293-310.

17. Fenichel, Carol Hansen. "The Process of Searching Online Bibliographic Databases: A Review of Research." *Library Research* 2(no. 2, 1980):107-27.

18. ________, "Online Information Retrieval"; and ________, "Online Searching."

19. Penniman, W. David. *Modeling and Evaluation of On-Line User Behavior* (final report to the National Library of Medicine). Dublin, Ohio: OCLC, 1981.

20. Brindle, Elizabeth A. "The Relationship Between Characteristics of Searchers and Their Behaviors While Using an Online Interactive Retrieval System." Ph.D. diss., Syracuse University, 1981.

21. Bellardo, Trudi. "Some Attributes of Online Search Intermediaries That Relate to Search Outcome." Ph.D. diss., Drexel University, 1984.

22. Woelfl, Nancy N. "Individual Differences in Online Search Behavior: The Effect of Learning Styles and Cognitive Abilities on Process and Outcome." Ph.D. diss., Case Western University, 1984.

23. Borgman, Christine L. "End User Behavior on an Online Information Retrieval System: A Computer Monitoring Study." *Association for Computing Machinery Special Interest Group on Information Retrieval. Forum* 17(no. 4, 1983):162-76; ________ . *End User Behavior on the Ohio State University Libraries' Online Catalog: A Computer Monitoring Study* (Research Report OCLC/OPR/RR-83/7). Dublin, Ohio: OCLC, 1983; Larson, Ray R. *Users Look at Online Catalogs: Results of a National Survey of Users and Non-Users of Online Public Access Catalogs. Part 2: Interacting with Online Catalogs.* Berkeley: University of California, Division of Library Automation and Library Research and Analysis Group, 1983; and Tolle, John E. *Current Utilization of Online Catalogs: Transaction Log Analysis* (final report to the Council on Library Resources. Research Report OCLC/OPR/RR-83/2). Dublin, Ohio: OCLC, 1983.

24. Matthews, Joseph R., et al. *Using Online Catalogs: A Nationwide Survey.* New York: Neal-Schuman, 1983.

25. Borgman, Christine L. "The User's Mental Model: Effects"; and ________ , "The User's Mental Model: Experiment."

26. ________ . "Individual Differences in the Use of Information Retrieval Systems: A Pilot Study." *Proceedings of the 49th Annual Meeting of the American Society for Information Science* (28 Sept.-2 Oct. 1986), vol. 23, edited by Julie M. Hurd, pp. 20-31. Medford, N.J.: Learned Information, 1986.

27. Woelfl, "Individual Differences in Online Search Behavior."

28. Borgman, Christine L. "Why are Online Catalogs Hard to Use? Lessons Learned from Information Retrieval Studies." *JASIS* 37(no. 6, 1986):387-400.

29. ________ . "Psychological Research in Human-Computer Interaction." In *Annual Review of Information Science and Technology*, edited by Martha E. Williams, pp. 33-64. White Plains, N.Y.: Knowledge Industry Publications, 1984.

30. Lancaster, F. Wilfrid, et al. "Evaluating the Effectiveness of an Online Natural Language Retrieval System." *Information Storage & Retrieval* 8(no. 5, 1972):223-45; and Sewell, W., and Bevan, A. "Nonmediated Use of MEDLINE and TOXLINE by Pathologists and Pharmacists." *Bulletin of the Medical Library Association* 64(no. 4, 1976):382-91.

31. Fenichel, "Online Information Retrieval"; and ________ , "Online Searching."

32. Penniman, *Modeling and Evaluation of On-Line User Behavior.*

33. Tolle, John E., and Hah, Seh-chang. "Online Search Patterns: NLM CATLINE Database." *JASIS* 36(no. 2, 1985):82-93.

34. Tolle, John E. "Understanding Patrons' Use of Online Catalogs: Transaction Log Analysis of the Search Method." In *Proceedings of the 46th American Society for Information Science Annual Meeting*, vol. 20, edited by F. Vondran et al., pp. 167-71. White Plains, N.Y.: Knowledge Industry Publications, 1983; and ________ , *Current Utilization of Online Catalogs.*

35. Borgman, "End User Behavior"; and ________ , *End User Behavior on the Ohio State University Libraries' Online Catalog.*

36. Dickson, "An Analysis of User Errors."

37. Taylor, Arlene G. "Authority Files in Online Catalogs: An Investigation." *Cataloging and Classification Quarterly* 4(no. 3, 1984):1-17.

38. Ibid.

39. Fenichel, "The Process of Searching."

40. ________ , "Online Information Retrieval"; ________ , "Online Searching"; Martin, W.A. "A Comparative Study of Terminal User Techniques in Four European Countries on a Large Common On-Line Interactive Information Retrieval System." In *First European Congress on Documentation Systems and Networks* (held in Luxembourg, 16-18th May 1973), edited by the Commission of the European Communities, Directorate General, pp. 107-67. Luxembourg: Commission of the European Communities, 1973; and Oldroyd, and Citroen, "Studies of Strategies Used in On-Line Searching."

41. Wanger, Judith, et al. *Impact of On-Line Retrieval Services: A Survey of Users, 1974-1975*. Santa Monica, Calif.: Systems Development Corp., 1976.

42. Fenichel, "Online Information Retrieval"; and ________, "Online Searching."

43. ________, "The Process of Searching."

44. ________, "Online Information Retrieval"; and ________, "Online Searching."

45. Matthews, et al., *Using Online Catalogs*.

46. Ibid.

47. Markey, Karen. *Subject Searching in Library Catalogs*. Dublin, Ohio: OCLC, 1984.

48. Kern-Simirenko, C. "OPAC User Logs: Implications for Bibliographic Instruction." *Library Hi Tech* 1(no. 3, 1983):27-35.

49. Johnson, M.F. "An Analysis of the Log of an Online Public Access Catalog." St. Louis: Washington University, School of Medicine Library, 1982 (unpublished manuscript).

50. Dickson, "An Analysis of Errors."

51. Taylor, "Authority Files in Online Catalogs."

52. Borgman, Christine L., et al. "Incorporating User's Information Seeking Styles into the Design of an Information Retrieval Interface." *Proceedings of the 48th ASIS Annual Meeting*, vol. 22, edited by Carol A. Parkhurst, pp. 324-30. White Plains, N.Y.: Knowledge Industry Publications.