Chapter 8. The Continuing Evolution of Information Seeking

Life is change; how it differs from the rocks (Jefferson Airplane, Crown of Creation).

Knowledge comes, but wisdom lingers (Tennyson, Locksley Hall)

As more information becomes available in electronic form, more systems are developed to support electronic information seeking, and more people gain experience using such systems, our overall expectations change and evolve about the value of information and the roles it plays in our lives. In the previous chapters we considered how technical developments have led to complex and rapidly changing electronic environments. These developments include:

- hardware advances in storage, processing, display, and networking;
- integration of application software such as text management, database management, communications, and hypermedia;
- retrieval algorithms and techniques such as inverted indexes, vector representations, and clustering; and
- human-computer interface developments such as user-centered design, direct manipulation, and graphical user interfaces.

These electronic environments have influenced information-seeking by amplifying what is possible in manual environments and requiring new information-seeking strategies. In this chapter, we summarize how electronic environments have already changed information seeking and examine some of the constraining conditions that moderate continued change.

EFFECTS OF ELECTRONIC ENVIRONMENTS

To examine how information seeking is affected by electronic environments, a distinction between physical and intellectual consequences of information in electronic form is useful. This distinction must be qualified as one of convenience, since physical and intellectual changes are interrelated. Physical changes include: greater volumes of information, remote access (allows users to transcend space), transfer speed (allows users to minimize time requirements), multiple formats and flexible management of those formats, behavioral actions of users, and capital investments. Intellectual changes include: alternative organizations, representations and access points; special tools and interfaces to support information seeking; interactivity (help and feedback); more focus on the information-seeking process itself; and new tactics and strategies.

Physical consequences of information in electronic form.
Electronic systems most obviously affect physical attributes of information such as quantity, time, location, and format.

Changes in volume. Paper-based information systems are more common than electronic systems today but the volume of information in electronic form may soon exceed that in manual systems. The predictions about paperless information systems made by technologists decades ago (e.g., Lancaster, 1978) were premature and overly-optimistic, but were prescient nonetheless. It is clear that manual and electronic systems will continue to grow and compliment each other, although electronic information will eventually far exceed paper-based information in quantity. The volume of textual information in a large research library is in the neighborhood of a few terabytes.[1] One Geostationary Operational Environmental Satellite (GOES) today generates 7.8 gigabytes on "non-event" days and over twice as much on days when hurricanes or storms are tracked more intensively--well over 3 terabytes per year. Furthermore, the Earth Observation System (EOS) will bring down about one terabyte per day! When we consider the volume of data the broadcast media transmit and maintain as well as the scientific data generated by huge international efforts such as EOS and the Human Genome Project, it is clear that electronic systems are essential for generating, collecting, and managing huge volumes of data in a variety of forms. Electronic technology allows the volume of information to increase dramatically by facilitating its creation and collection as well as by providing possibilities for managing larger collections[2].

Changes in time and effort. Electronic environments can support enormous savings in time and effort. Although document delivery systems are still in their infancy, using tools such as an online catalog or full-text database from one's home or office can save trips to libraries or information centers. Several document delivery services are available through OPACs and online services to allow information seekers to search journal literature and order fax or paper copies of articles by simply entering a credit card number. Even in today's rather primitive electronic networks, it is possible for users to access enormous data sets, bibliographic databases, and primary literature anywhere there is a network connection. Immediate access from any site makes possible virtual libraries that "exist" wherever and whenever an information seeker with proper authority and resources needs it. Access, however, is necessary but not sufficient for successful information seeking. Access time and effort are dramatically improved by electronic environments, but access does not insure extraction of relevant information. Although it may be argued that these changes in volume and accessibility are simply quantitative rather than qualitative, Kay’s (1984) example of the qualitative difference between many individual static images and those images at 20 frames per second is illustrative. Quantitative changes can be the basis for qualitative change.

Changes in format and management. More subtle than the changes in volume, speed of access, and remote access, is the flexibility in format provided by electronic environments. Multimedia computing is a strong growth area for the computing and information industries as electronic systems are better able to support text, sound, and static or moving images (Fox, 1991; Koegel-Buford, 1994). Although most information environments support multiple formats, the capability of electronic environments exceeds such capabilities in paper-based or broadcast systems in two important respects.

First, electronic environments shift some control of manipulation from the producer/distributor to the end user--they make information products malleable. Authors, broadcasters, and other disseminators traditionally provide stable information packages that consumers use as is. Users may mark or highlight their copy, extract quotations for use in another work, or even make a complete copy, but digital representations of these packages clearly simplify extraction (e.g., cut and paste) and copying, and also permit more radical possibilities for users to edit according to their needs. Presently, there is no way to tell whether a digital product has been edited; moreover, digital products are easily copied and transmitted to many other potential users. Paper-based information is static; films, videos, and sound recordings provide linear dynamics but are typically not editable by users. Digital representation allows reordering and editing. Some schemes to represent a variety of information formats in digital forms for computer-based systems provide full dynamic possibilities for end users. Nelson's Xanadu (Nelson, 1987), for example, promises full access and manipulation to the universal corpus and permits derivations to be easily added with credit and appropriate payments managed automatically, although the practicality of his approach has been questioned by Samuelson & Glushko (1991).

The technological possibilities obviously lead quickly to intellectual implications. Consider, for example, the differences between downloading a film and substituting characters or changing character attributes to satisfy personal tastes, with changing the actual date of the Battle of Hastings in an electronic encyclopedia to a date that fits the needs of a term paper argument. As multimedia workstations become the norm rather than the exception, users will be able to integrate more easily text, sound, and graphics. Some producers will ultimately develop malleable products that take advantage of such integration. Although electronic environments provide the potential for local control over information, the economic realities of the marketplace cause producers to create products aimed at a lowest common denominator of technology. Thus, although many users may have excellent display devices, products may not take advantage of those capabilities since they must operate in a broad installed base of equipment. Additionally, control over the intellectual rights of information mitigate against rapid developments in fully-manipulable, digital products. One of the dilemmas of government and the publishing industry is how to assure fairness in protecting intellectual property rights in an environment where every user is empowered to create and easily transmit derivative works.

Second, multimedia information extends intra-object and inter-object connection and integration. Figures and tables are closely connected to text in paper-based systems, and textual graphics are carefully integrated with visual/verbal information in television broadcasts. Electronic environments support these types of connections but provide possibilities for alternative connections dependent on user choices or computed conditions. Books or films make reference to other works through citation and allusion, but electronic environments broaden proximity and invite hypertextual links across information objects and formats. In reading a Sophocles play, each line requires the reader to make mental connections with past experience and knowledge. If a mouseclick offers twenty images of vases, sculpture, maps, and related ideas expressed in other texts, then the experience of each line may potentially be enriched enormously. Realizing these riches comes at the cost of time to examine the related objects, and the possibilities of endless discursions.

A problem of reading in such an environment becomes curtailing connections rather than suffering from lack of details--instead of starving for the explanatory information sometimes found in footnotes, the reader may gorge on detail and miss the total experience of the feast. Additionally, there may be learning benefits associated with having to puzzle out some connections--discovering connections is surely one of the most intellectually stimulating activities. The degree of connectedness of information in electronic form has, in fact, changed the concept of what is a document. Bolter (1991) argues that the multiple windows and hypertextual connections of electronic environments make even scholarly documents more like newspapers or magazines that pull readers back and forth among the various blocks of text, ads, headlines, and images. Users must parse windows and icons as well as textual structures while browsing, reading, and studying electronic information. At present, we have no guidelines for managing such richly-connected intellectual worlds.

Changes in user actions. Information in electronic form changes the physical actions that people take during information seeking. First, we sit at workstations using primarily our eyes and hands to locate, examine, and extract information. Such access is physically passive, saving time and effort related to physical actions such as travel, reaching, and turning pages. Loss of the physical exercise entailed by information seeking may be doubly disadvantageous to intellectual workers who already get little physical exercise as part of their work day. The effects of eye and muscle fatigue and repetitive movement injuries are becoming more apparent, and concerns about radiation surface periodically in the human factors literature. Although video display terminals provide the advantage of dynamic display of multiple formats, people read electronic text more slowly than paper-based text, few people can now afford broadcast-quality video on their workstations, and few argue that reading on screens is more comfortable than reading on paper. Thus, electronic environments bring tradeoffs related to the physical actions of information seeking.

Second, we must learn to work in these environments. Substantial investments in time are required for users to become computer and information literate and to learn to use specific applications. Billions of dollars are spent on training workers to use systems and specific application packages. Additionally, computer anxiety has been estimated to influence about one-third of all new users (Torkzadeh & Angulo, 1992) and there is need for policies and programs to deal with this general problem as we approach full saturation of computers in the workplace. Third, working in electronic environments may lead to physiological/psychological changes. Huge volumes of information require substantial amounts of time and effort and may overload users and lead to physical reactions to such stress. On the other hand, the potential to provide information in multiple formats allows users to personalize information display to their individual styles, abilities, and preferences.

Changes in resource allocation. In addition to the substantial costs associated with adding electronic environments to our personal information infrastructures, the capital costs of technology for public information infrastructures is a significant concern. For example, millions of dollars have been spent on library automation in the past decade but we have no clear evidence of how this has improved access let alone productivity. When we consider the materials (e.g., books and serials) that were not acquired and services not provided (e.g., reference) because funds were used to acquire and install OPACs, CD-ROM workstations, and library networks, the changes electronic technology have already brought begin to come into qualitative focus. Data collected by the Association of Research Libraries (Cummings, et al, 1992) illustrate that operating expenses (the component of library budgets that typically include automation costs) have shown generally steady growth as a proportion of the overall budget from 1963 to 1991, while salaries and binding portions have generally gone down, and materials acquisitions have remained generally fixed. Dreams of amortizing capital costs for technology over time so that more and better access is provided are surely mitigated by ongoing maintenance and upgrades and the influence of shifting resources from people and information is difficult to assess. What we know for certain is that electronic environments have changed the resource mix.

Similar changes have occurred in business, government, and educational settings. Other costs, such as security, reliability, and dependency on electronic systems for basic public services are beyond the scope of this book but must also be taken into account (see the Risks Column of <u>ACM Communications of the ACM</u> for examples of costs and risks related to computing applications).

Intellectual consequences of information in electronic form.
We have been primarily concerned in this book with the intellectual changes that electronic environments bring to information seeking. These changes are primarily related to how information is organized and represented in information systems and how information seekers interact with these systems to access and use information.

Changes in organization and representation. Electronic storage capacities support large databases at multiple levels of granularities, and computational power allows system designers to apply a variety of preprocessing techniques to support multiple access points (e.g, indexes), and to apply decision rules that depend on conditions at run time to provide alternative representations for information (e.g., user-sensitive interfaces). Ultimately, all levels of representation will be integrated, but during this transitional period two gross levels of representation are supported in distinct secondary (e.g., bibliographic) and primary systems. For each of these types of systems, electronic technology has brought significant changes.

Electronic bibliographic systems offer more access points and yield larger sets of potentially relevant documents than manual systems. For example, although OPACs have been slow to move beyond simply automating the card catalog, most provide more than author, title, and a few subject headings as access points. Keyword indexes and automatically expanded controlled subject heading assignments have been made possible by computational power. We are only beginning to explore richer indexing, including personalized indexes for OPACs and database directories. Furthermore, the availability of OPACs through networks provide world-wide access.

Online databases allow users to focus queries on specific database fields. Some offer dozens of access points, for example, business databases allow users to search with specialized indexes for geographic region, members of boards of directors, and various financial parameters. Indexing a broader collection of attributes (i.e., creating more indexes) provides more links into documents. More access points per document complicates the types of queries users can generate and changes the probability of retrieval with respect to these queries. Taking advantage of indexing on a broader range of attributes thus requires information seekers to have and use more knowledge about how information is organized and also tends to increase the number of documents returned.

Technology has changed indexing practice by altering the number of subject terms assigned to each document. Without any changes to the controlled vocabulary used to assign subject terms, more terms can be assigned to each document since additional physical cards or additional lines of text are not needed. Indexes can apply as many terms as appropriate without the constraints imposed by physical objects for each entry point. Alternatively, the controlled vocabulary itself can become larger. Allowing all content-bearing words in titles is a common extension to the assignment of controlled terms (keywords). These additional access points yield more items for a query than more parsimonious indexing. The large sets of results, can of course burden the information seeker, and better tools for examination of these results are needed. This is a primary motivation for developing interfaces that support efficient browsing of document sets.

Some online systems provide multiple indexes and links to related objects. Citation databases have benefitted immensely from computers, growing from simple citation compilations to systems that allow cocitation analysis and bibliographic coupling (Garfield, 1955; Paisley, 1990). The earliest electronic systems represented well-defined, bibliographic pointer information modeled on database designs, and these models shaped the expectations and strategies of information seekers. Users already use bibliographic databases to explore rather than retrieve and as these systems move beyond simple exact matches on well-defined fields, new expectations and strategies will emerge. Most obviously, users will expect to gain immediate access to the primary material and to use the same interface tools and techniques to work in both types of materials.

Primary information is increasingly available in electronic form and this is causing new levels and forms of representation as well as new types of human-computer interactions. The availability of primary information in electronic form is a significant trend and creates new demands for intermediate representations between terse surrogates and full documents. Full-text and other primary information sources also demand new information-seeking approaches and strategies. Reference materials such as encyclopedias, atlases, and almanacs; technical publications such as newsletters and research updates; and communication forums such as electronic mail, bulletin boards, and listservs have led to new layers of representation across and within individual items.

Electronic systems have begun to blur the distinctions between secondary and primary materials and the respective search strategies for across and within document searching. This melding is due to several factors. First, the same physical device is used to conduct both types of search--the same computer and display are used for searching for a document as for reading the document. Second, each information item can be represented at differing levels of detail, from a terse bibliographic record, through various intermediate abbreviations, condensations, or extracts, to a full explication of the entire item. Information seekers can work at any of these levels and may use the same control mechanisms or tools to search, browse, and study across multiple documents or within specific ones. Third, the increased connectivity within and between information allows users to move across documents and levels easily--whether they actually want to or not.

In manual systems, there is a clear distinction between secondary and primary information sources. Printed indexes provide citations (very coarse representations such as a title) for books or journals (distinct objects containing primary information) that may or may not be physically proximate. A similar situation exists in the bulk of electronic systems today. OPACs and online bibliographic databases point to articles, books, and reports that may be inaccessible to the information seeker[3]. As designs move beyond replicating print-based organizations, we will see these distinctions blur. Document delivery services are increasingly available from online systems, and large primary corpuses often provide sophisticated within-document search tools as well as links to related primary materials. Additionally, primary documents have multiple levels of representation, for example, tables of contents, chapters, sections, paragraphs, etc. At present, interfaces are emerging that allow information seekers to take advantage of these levels almost as easily and naturally as they do in paper-based sources. In time, these interfaces will improve to go beyond what is possible for searching and browsing paper-based sources.

As full-text and multimedia databases become more common and we develop principles for designing interfaces for them, distinctions between secondary and primary databases will disappear. Secondary and tertiary information will simply be viewed as two of many levels of representation in an integrated information space. Ultimately, a major structural change will emerge that views information as a continuous space rather than as a collection of discrete sets of documents and pointers. One dimension of this space is composed of a series of representations for an intellectual work (e.g., a book, a film) and other dimensions consist of connections to other intellectual works at various levels of representation. For example, a collection of titles are connected according to some dimensional parameter such as publisher, date, or concept cluster; and a specific book chapter is connected to several other chapters or articles or film segments according to subject, style, or other attributes. In sum, electronic environments have already provided richer and more varied representations in a single location than manual environments and this trend will continue to accelerate in the future.

Changes in intellectual tools. A significant difference between manual and electronic environments is in what software tools and interfaces are provided. Much of the previous two chapters are devoted to such interfaces. In general, electronic environments can provide a range of computational tools and dynamic feedback that fundamentally changes the information-seeking process. These include:

- Data dictionaries for different databases, term dictionaries and thesauri, and menus or query completion forms may be used to assist in source selection and query formulation;
- string search, highlighted query terms, multiple windows, hypertextual links, and graphical displays may be used to aid in examination of results;
- cut and paste tools and annotations may be used to support information extraction; and
- search history tools, grammar or statistical tools, and online help may be helpful in reflecting, iterating, and terminating search and in refining the information problem.

Electronic environments offer basic search functionality that is difficult or impossible in manual environments. Combining concepts according to Boolean or proximity limits is extremely tedious in manual environments, but made simple by careful preprocessing in electronic environments. Limiting search to specific ranges or fields is likewise simple in electronic environments. This functionality provides awesome power for formulating precise and complex queries that match well-specified attributes of tasks and documents. A consequence of this power is that users and designers often neglect the specification restriction and assume that information seeking is strictly a matching process. As has been argued throughout this book, information seeking is a dynamic problem-solving process and matching is but one aspect.

Changes in interactivity. Electronic environments change the way we seek information by offering high levels of interactivity. Rapid feedback provides a sense of interaction, and carefully planned programs suggest "intelligence" by acknowledging input, offering "suggestions" or critiques, and giving help on request. Although we have much to learn about online help and documentation, (see Brockmann, 1990 for an excellent overview of electronic documentation, and Carroll & Aaronson, 1988 for a framework for online help) electronic environments offer users much greater flexibility in learning and using the system than is possible in static, manual environments. Context sensitive help provides focused assistance and transaction logs provide historical contexts for specific sessions or across many sessions. Electronic critics (Fischer & Girgensohn, 1990) provide advice triggered by chains of events rather than single instances. Online reference materials, by virtue of their electronic format, offer users the same type of search and display properties that make electronic documents more flexible than paper documents (e.g., searchable on multiple keys, customizable display, highlighted terms, visual juxtapositions of disparate items, etc.).

All these specific attributes combine to provide information seekers with a highly interactive environment that engages us in more fine-grained steps and more iterations of activity than manual environments. More access points, more tools, more immediate feedback all lead to a process that is highly specifiable. This result is significant and leads to secondary changes such as inviting broader communities of users, changing the expectations of users and the strategies they apply for information seeking, and ultimately changes the way that information is organized and how systems are designed to make that information accessible.

One consequence of having primary and secondary information in highly interactive, electronic form is that more end users are attracted. We are able to delegate bibliographic searches to intermediaries but ultimately must do their own browsing and studying in primary materials. If increasing numbers of people are using electronic systems to work with the primary information, they may as well use the system to locate that information in the information space in the first place. End-user searching is a double-edged trend. Electronic environments have empowered end users to broaden and improve their personal information-seeking infrastructures. Presumably, this has also led to better and more efficient solutions to information problems. However, these benefits are not without costs. In addition to the physical costs discussed above, information overload, confusion, and disorientation are increasingly problematic.

These contraindications are of two types: those that stem from the system itself and those that emanate from the information accessed. In the first case, the disorientation of menus systems, hypertext, and other access mechanisms are well-documented in the literature. These problems are mainly technical and will likely become less troublesome as computing becomes more ubiquitous and user interfaces improve. The second case is more problematic since it is a result of human mental capabilities. We can only hold so much information in our heads at one time and there is no technical solution to information overload. The best we can hope for is to use the technology to augment our limited memory capacity. In essence, electronic environments broaden access to a larger community of people and widen the resources available for individuals to solve information problems, but also demand new skills and do not diminish the need for people to think.

Changes in our view of the information-seeking process. Electronic environments have begun to change the way we think about information seeking as well as the strategies we use to do it. The impatience that users demonstrate while waiting a few seconds for the Perseus system to locate and load graphic images or conduct morphological analyses of Greek words illustrate the fundamental change in expectations that computers bring with respect to temporal matters. No one would expect it to take less than ten seconds to go to a library, locate a book containing a photograph of a vase, and find the right page, but everyone becomes impatient waiting for the computer to execute such a task. Just as our expectations about time have changed, developments in computational and display capabilities lead us to expect high-quality displays of text, images, and sound augmented by comprehensive annotations. Likewise, users are beginning to expect document delivery rather than bibliographic pointers. In an age of fast food, jet travel, and global telecommunications, our expectations about the time needed to seek information and the quality and breadth of information available have evolved beyond the physical limitations of manual systems. Electronic environments heighten our expectations about information access, however, as always, the ultimate bottleneck is our physiology and psychology--we still must perceive, process and comprehend information if we are to achieve our goals.

Changes in our expectations about time have led information seekers to focus more attention on the information-seeking process--large changes in time to accomplish tasks makes us more conscious and reflective about what has changed. This shift in attention and effort has implications for those who use information and those who work at finding it. Many strategic and tactical alternatives, and multiple access points imply decision making; high levels of interaction imply active participation; and the power and volume of electronic information systems require more evaluation of results. Since our cognitive capacities are limited, the effects of channelling significant amounts of cognitive resources to the search process rather than on the problem and content at hand needs careful examination. This may be good in the long run since problem definition is constantly engaged, but it may also lead to missed opportunities for study and careful concentration.

Professionals allocate relatively fixed amounts of time to seeking and reading information on the job (Griffiths and King, 1991). Although the proportion between seeking and reading may change, the total time available does not. Thus, time devoted to finding comes at the expense of time for reading. These results are used as one of the rationales for providing information retrieval services, thus allowing the engineer or scientist to maximize reading and studying time. It is too soon to know whether increasingly more integrated electronic environments will make it counterproductive to disassociate seeking and reading information. If seeking and reading are inextricably interlinked, then people may spend less time reading and studying, and information specialists will spend less time finding information for clients and more time collecting, organizing, and evaluating it.

Changes in tactics and strategies. In the previous chapters we explored how electronic environments first led to powerful analytical search strategies and are beginning to support highly interactive browsing strategies. Information seekers expect to use more guess and go strategies that allow them to quickly isolate materials to browse for possible answers, leads, and ideas. Browsing strategies that take advantage of alternative representations and highly dynamic mechanisms have become practical; these expectations about information seeking lead to more dependence on such strategies and to the need for interfaces that support them. Additionally, new strategies for systems that support relevance feedback and that search multiple databases in parallel will develop as users gain experience.

It is important that in our efforts to accommodate these changes we do not neglect to develop and revise analytical strategies that allow precise query specifications. String search and Boolean search dramatically changes what is feasible. Although theoretically possible in manual environments, these strategies have become minimum features in electronic environments. Systems that provide ranked retrieval will spawn new analytical strategies as users learn to exercise precise control over term weights and automatic query expansion parameters. Our wants are infinitely beyond our needs, and our expectations about the world almost always err on the side of optimism.

Subject access is the grand challenge of information science and the most grandiose claims for electronic environments have been focused on this problem. There are two distinct approaches to the challenge of subject access. By far the most common approach is to assume that the "aboutness" of a document can be ascertained and represented. This belief obtains matching information problem representations to document representations as the fundamental operation of information systems. This view is rooted in scientific philosophy that assumes that information and human behavior can be studied and understood from an external, objective vantage. Indexing and various knowledge-based representation schemes adopt this approach to the challenge of subject access. It is attractive because it allows people not directly involved in the production or use of information to play a role--either adding value to support matching operations or as intermediaries working to find matches. This approach is clearly viable since it is partially successful and supports an entire industry. Computation is useful to this approach is several ways. First, computers can be used to aid in the indexing process or possibly to replace human indexers (e.g., Milstead, 1992). Second, computers can provide alternative views of information to end users, for example, different indexes, or different levels of record detail. Third, computers can support complex matching mechanisms such as Boolean combinations and rapid string matching. Alternatively, computers can be used to determine approximate matches and rank results according to any number of computational schemes (e.g., statistical or probabilistic approaches).

An alternative approach assumes that all information may ultimately be related in some way to all information problems--the creative problem solver takes what information is available and applies it to the problem at hand. This belief views subject access as situation dependent and the function of the system is to provide rich source material. This view is rooted in humanistic philosophy that assumes that information and human behavior are personal and contextual and can only be studied and understood from an interpretive, subjective vantage. Computation is also useful to this approach in several ways. First, computers may assist in accessing and representing information rapidly, efficiently, and according to the individual needs of the information seeker. This access can be based on individual user experience and knowledge rather than some standardized scheme. Second, computers may be used by individuals to manipulate information according to their personal information needs. Personalized indexes or ontologies (Wiederhold, Wegner, & Ceri, 1992) may be defined and used. Third, computers can support alternative or customizable interfaces and tools for representation and manipulation. Although it appears a bit ironic that logic-based tools such as computers should be so applicable to a human-centered view of information seeking, it is the development of highly flexible electronic environments that has rekindled the possibilities for this approach. The connectivity, virtuality, and malleability of electronic environments can lead to decentralization and personal freedom, and enable natural, human-centered approaches to information seeking. Imagine the discoveries and connections that children will make as they explore the world-wide networks. Such images are in sharp contrast to the efficient and targeted inquiries busy professionals demand from highly organized electronic environments. Both views are necessary. Just as electronic environments have spawned new analytical and browsing strategies, they create new expectations and ultimately new behavior and thought.

CONSTRAINTS AND CHALLENGES FOR CONTINUED EVOLUTION

There is a lively literature related to the relationship of technology and society. Points of view range from "gee whiz" prognostications about the future to Luddite-like trepidation; some view technology as value-free and others as the means for despots or governments to control society; and some address the "chicken or egg" problem of whether society creates technology or vice versa (see Teich, 1990 for a collection of diverse views). Technology influences culture and is shaped by the culture in which it exists. To some extent, technology is shaped by the needs of society; more importantly, society does not undergo all the changes that technology may enable. Taviss (1972) discusses the social and cultural adjustment that must be made with the introduction of technology. Andriole (1984) argues that technology has already changed the nature of risk in our world and examines various security issues related to large information systems. Forester and Morrison (1990) provide a good collection of examples of how computers have affected individuals and institutions. Mesthene (1968) argues that technology causes intellectual, social, and political changes, and that the ways that knowledge is sought and created change as knowledge gains in social importance. Information technology is subject to these strong interactions. There are many social and political factors that influence the evolution of information seeking. A few of these factors are discussed in the following.

Physical, economic, and technical constraints and challenges.
Ideas and their representations are limitless in number but their physical manifestations consume resources and occupy space. Manual information systems pose obvious constraints on growth and access. Offices can only support so many filing cabinets, and libraries regularly struggle with lack of adequate shelf space. Electronic technology appears to overcome this constraint by improving storage densities many orders of magnitude over paper or film-based systems. Electronic technology will continue to improve, but it is inescapable that matter and energy are ultimately consumed and physical limits to what can realistically be made accessible will influence acquisition and access. More importantly, access severely constrains the "save everything" mentality since without proper indexing, finding information becomes impossible. There is a critical need for a life cycle view of information so that dispensation decisions are considered at the times of creation and storage. Archivists may offer some guidance in developing such strategies (Burke, 1981). Although the present antidote to the "save everything" mentality is the difficulty of intellectual access, physical limitations are also at issue.

A central theme of this book is that technological developments have already influenced the evolution of information seeking. There are many technical challenges that limit as well as cause change. Hardware and software developments will surely continue to drive many of the changes, but interface design and implementation offer severe challenges to progress. Multiple, portable, unobtrusive, physical devices that allow transparent control and high fidelity feedback must be developed. As information seeking becomes more like thinking--wondering, free-associating, remembering--our physical links to the external world of information may become less distinct as input or output devices and more like multi-directional channels among our local and remote information resources. For example, Bolt (1984) has offered novel examples for using eyes as output devices to control as well as perceive the world. Beyond such engineering challenges are the conceptual interface challenges to organize, represent, and make manipulable the world's information resources. Discovering different representation forms and levels, creating meaningful connections among the various representations and related corpuses, and presenting mechanisms that support easy interpretation and control are huge design challenges. Creating systems that are personalizable according to the special physical, intellectual, and emotional needs of different information seekers will continue to constrain how information seeking evolves.

Many of the constraints that influence information processing in general are economic in nature. Most obviously, there are enormous capital costs in the hardware and software components of electronic environments. Although immense technological investments have been made by all economic sectors, there is no clear evidence that productivity, quality, or satisfaction gains commensurate with these investments have followed. In fact, it may not matter from a global perspective since the new products, jobs, and markets that electronic technology entail have caused overall economic growth. Individual people and corporate entities must, of course, consider these capital expenses in light of their local economic parameters. Many economic constraints are more subtle and interact with the psychological, social and political factors considered below.

Intellectual property, authority, and copyright.
Governments provide legal protection for intellectual property rights to assure the long-term continuation of innovation and progress. Fair returns on intellectual effort reward creators and distributors and provide continued access to the community. As technology changes how information is created, organized, shared, and used, legal and economic factors must also evolve. One aspect of electronic information is the ease with which it may be copied. Photocopy machines assaulted copyright laws, but mass copying of printed material still requires significant investments of time and material resources. Furthermore, photocopies degrade in quality over generations. An electronic document can be as easily copied to a hundred network addresses as to one floppy disk, and if these recipients choose to copy to others, each subsequent copy is an exact replication.

Even more problematic is the malleability of electronic documents. Photocopies cannot be changed, but electronic documents can be edited without leaving any traces of editing. Creative authority is distinct from the issues of property since reputations and beliefs are foremost--an author may not care about monetary royalties but may care a great deal about the accuracy of reproduction and receiving intellectual credit for ideas.

Electronic documents can be easily altered without the permission or knowledge of the author and authoritative warranty schemes (electronic versions of tamper-proof packaging or shrink wrap) are required. Bit-mapped images (pictures of text or graphics such as those provided by fax machines) may be easily copied but they cannot be easily edited and thus provide some level of editorial integrity. This is only a temporary delay in the transformation from paper to electronic publishing and we will ultimately need new rules and techniques to assure fair use and editorial authority for electronic information. Certainly, video editing software packages have already destroyed the authority of any digitally stored video.

Electronic technology raises new intellectual property issues. Electronic networks facilitate collaboration among people and pinpointing ownership or crediting contributions in such environments is difficult. Text fragments from listservs and discussion groups, algorithms and code fragments from software libraries, graphics from clip art libraries, and databases or knowledgebases from governmental systems are commonly aggregated and modified to create new intellectual works. Digital slide libraries and video archives complicate this issue. Reusability is an ecologically positive trend, but it is unclear what property rights accrue to the various creators. A similar problem has emerged with respect to the "look and feel" of interfaces with some arguing that "look and feel" is a definable intellectual property (e.g, Shneiderman, 1993) and others that it is not (e.g., Samuelson, 1992). Much of the debate centers around whether the interface is functional (and therefore not copyrightable) or expressive (and therefore copyrightable). One side argues that since good design is informed by research and theory, the products are not copyrightable; an alternative view is that the sum combination of well-designed displays and mechanisms is a creative expression and therefore copyrightable.

Another issue is related to the notions of added value and derivative works. Significant components of the information industry profit by packaging and selling information produced or collected by government agencies. Likewise, publishers create books of readings derived from existing publications. Aggregating, organizing, packaging, and distributing all add value to information and for many years it was enough to simply take paper-based documents and transfer them to electronic form to justify reselling public information. As more government information originates in electronic form and as industries (e.g., security and exchange reports) and individuals (e.g., tax returns) actually provide information in electronic form, information brokers must find new ways to add value. Governments are beginning to take advantage of technology to aggregate, index, and distribute information as part of their service mission. As information brokers develop new forms of displaying and linking information, new clarifications are needed to decide when enough value has been added to justify copyright claim. Three different vendors' CD-ROM versions of the same database can provide distinct levels of performance and satisfaction. Clearly, customized indexing, links to other information sources, and interfaces for locating and using information are added values that will continue to define markets for derivative works.

A classic form of derivative work is an edited volume of previously published papers. An editor provides a valuable service by selecting papers that represent interesting themes, may provide an introductory framework for the selection, coordinates copyright acquisition, and assists the publisher in shaping marketing and distribution. For paper books, the property issues and copyright arrangements are well-established. It is less clear what policies should be followed when a collection of printed papers are aggregated and linked as a hypertext. The intellectual effort of forming links requires substantial editorial interpretation and effort. In addition to editorial rights and responsibilities, authors rights become more complex.

One issue relates to situations where hypertext navigation may juxtapose a segment of an author's work to segments of other work. Because links may be made at fairly fine-grained levels, this is quite different than having one's article included as a chapter with another article that expresses a differing view. In the case of hypertext, specific passages may be linked without benefit of the surrounding context in which they occur. In essence, parts of one author's work may be embedded in another author's work or the two or more works can be multiply intermingled in a variety of ways. Another issue is related to ownership of links. Links are editorial acts, and thus may be considered the intellectual property of the editor. Authors of nodes, however, may claim ownership of links coming in or going out of their works (Samuelson and Glushko, 1991 provide a good discussion of these issues). If the highway system is used as a metaphor, the problem becomes one of determining exactly where public streets become private drives and how private drives are demarcated and connected.

As discussed in the previous section, electronic environments blur distinctions and roles for those who use them. In electronic publishing, the roles of authors, publishers, and consumers also blur. The fluidity of electronic environments break down classical distinctions and create new challenges for governments to provide legal guidance, for libraries to provide access, and for business to assure fair return on investment.

Social and political constraints and challenges.
The notion of ownership of information ignites lively debate between those who view information as a commodity and those who view it as a right. Devotees of free enterprise point to the progress engendered by competition in the marketplace. They argue that anyone should be able to profit from their intellectual effort and that the market should determine how much people should pay for access to information. This position lends itself to privatized information networks and metered use of information services. Devotees of social management point to progress engendered by cooperation and community programs such as public safety and education, and other government services. They argue that information is a birthright and should be made freely

available to anyone who needs it. This position lends itself to public libraries and information networks that provide equal and unlimited access to all. Since governments are leading producers of information, policies for making information available to the public will greatly influence how information seeking evolves. Policies may make all, some, or none of the information governments generate freely available. Policies range from mounting all government databases on the Internet for free access to subsidizing the information industry by releasing all government databases to vendors who provide dissemination and value-added services commercially. Different governments will determine different levels of basic information rights for its citizens, thus determining equity of access for fundamental corpuses such as legal and medical databases.

Of course, providing free access to information is only part of the equity problem. People must be aware of the availability of information and possess the skills to access and use it. Public libraries in the United States have served as the "poor person's university" because those who learned the basics of reading could gain access to the main elements of the world knowledge fund. Just as reading skills are necessary to take advantage of libraries, reading skills, computer skills, and information-seeking skills are increasingly necessary to take advantage of the virtual library and world-wide information networks. Those who are privileged to acquire such skills as part of their education are greatly advantaged over those who do not. Clearly, not all people will become equally facile in these skills, but all should be assured of some basic levels of skill. The degree to which all the world's people acquire such basic skills will influence the continued development of electronic information seeking. This is so because provision of minimal, standardized, and culturally diverse interfaces will mitigate rapid changes as a larger mass of users acquires habits and preferences. Consider the following argument from a mass/inertia perspective.

Information technology has created new industries and is beginning to influence the social and cultural milieu. The early stages of any innovation are chaotic and revolutionary; characterized by rapid changes, lack of standards, missionary zeal on the part of developers and early adopters, and high risk decision making. Eventually, entropy begins to build, different levels of stability arise, and an installed base of objects, procedures, and thinking becomes important. As the installed base grows, the energy needed to influence its inertia becomes greater and the probability of change decreases. Electronic technologies have certainly been among the foremost innovations of the second half of the twentieth century, but the pace of change in electronic environments cannot be maintained. The installed base of equipment, software, user knowledge, and institutional policies has grown beyond the early adopters to the general population at large. The policies, skills, and biases related to it will continue to evolve, but the rate of change must diminish because so many people participate. Stabilization will allow basic skills to be more globally learned.

Another cultural constraint that influences how electronic information seeking will evolve is related to the nature of ownership. Many people take pleasure in possessing things, and some people enjoy possessing information artifacts such as books, videotapes, or videogames. Just as libraries have not put bookstores out of business, video rental centers also sell videotapes and games. This will likely continue in the future but much more focus in being placed on access to information rather than ownership. This is clearly the case in libraries struggling to maintain large research collections and it is reflected in the number of resource-sharing consortia in business and industry. The shift from ownership to access is a fundamental change in perspective that is also reflected in the economic movement from manufacturing to service. What are the information complements of this trend? A statement most teachers hear sooner of later from their students is: "I really do not have to know this, I just have to know where to find it when I need it." By this reasoning, learning is the development of a mass of indexes to knowledge. This is a highly positivistic view of the mind as an organized system of pointers and knowledge. A wholistic perspective is that the mind is a fabric of experiences and reflections. Associations and organizational structures are imposed after the fact. The ultimate augmentation of the intellect by computers may be to serve the indexing function allowing humans more time and effort to acquire primary experience and knowledge.

Subject access and information problems.
Technology may have changed the things we choose to think about, the strategies we use for directing our thinking, and the behaviors we exhibit when thinking, but thus far it has not changed fundamental physiological processes associated with thinking. Likewise, technology has changed the way we represent and share expressions of thought, but has not thus far changed the fundamental forms and rules of language and communication. The basic problem of conceptualizing an information problem and translating information from the external world to solve that problem has not been much affected by technology. Consider how hard the problem really is! Concepts are manifested through some finite expression of tokens from a language--eventually the book or painting is finished and there are enormous varieties of tokens left unexpressed that could also have been used to express the creator's ideas--one instantiation of a creator's noumenal clouds have been expressed. Any expression is but one possible form for the concepts, ideas, and feelings of the creator. The problem of understanding such expressions is likewise imperfect since the receiver may associate many ideas with the specific tokens perceived. Communication is a creative process and it is redundancy and shared experience that permit usable levels of effectiveness. The process is even more problematic when one is seeking information rather than trying to understand what is being communicated. This is so because we have to imagine the tokens that may have been used to represent ideas relevant to our information problem. This is doubly difficult since lack of understanding (the information problem) means there are meager sets of likely tokens for the problem. That is, we have difficulty expressing what we do not understand, let alone imagining the tokens used by those

that do understand. The novice cannot guess whether the brush strokes, color combinations, or shapes are the tokens of greatest interest in an abstract painting. This is essentially the problem of subject access--imagining how creators expressed ideas.

Indexing and classification were created as bridges between the information seeker and the creator. The flexibility of electronic environments can broaden and extend the bridge[4]. A thesaurus or controlled vocabulary serves to standardize some set of tokens where information items and information seekers can meet. This is a fundamental problem of representation and communication and electronic environments offer some possibilities for addressing part of the problem. Solving the problem fully means eliminating creativity and interpretation--whether we can do it pales by comparison to the question of whether we should do it perfectly.

One of the ways that technology has begun to influence subject access is to provide possibilities for automatic indexing that affect the costs of producing indexes, and as a result, the potential for additional or alternative indexes for individual works. Although it seems apparent that a carefully handcrafted index may be superior to an automatically generated index, the time and effort tradeoffs are substantial. Additionally, there may be some global advantage as more indexes are generated automatically, e.g., off-the-shelf clothing has improved the variety and quality of clothes for humans in general. Automatic indexing may ultimately provide multiple indexes for most purposes, and handcrafted indexes will be reserved for only the most important or unique documents. Furthermore, it is possible that end users themselves may use these tools to create their own alternative indexes.

The availability of full-text searching has so far been the most prominent change resulting from computers. Indexing items for every word that appears greatly increases the number of tokens that information seekers may use to identify those items. Although this change can dramatically improve the retrieval of specific items, it has three important limitations. First, even though all words are available as potential tokens for information seekers to use, unless supplemental indexing is provided, there exist tokens not used in the work which may nonetheless be useful expressions for the ideas in the work and that information seekers may actually use as entry points during information seeking (i.e., an author does not use a particular word or phrase although it could just as easily have been used). Second, since items may contain large numbers of tokens and specific tokens may have multiple meanings, items that contain tokens that are present in queries are not necessarily appropriate in degree or kind--there will be many peripherally useful items retrieved. These two problems are a direct result of the richness and imprecision of language. Third, because searches are usually initiated in collections of items, the number of items that may contain specified tokens may be quite large. If each unique word with the exception of some stop words serves as a retrieval cue, then each document will have hundreds or thousands of tokens. The number of items with common tokens grows as a function of the size of the collection if all unique terms are indexed. Term weighting based on inverse document frequency or other normalizations can minimize this problem but simple queries posed to large databases will still return large numbers of highly ranked documents. In collections where controlled vocabularies are used for indexing, the number of overlapping items also grows monotonically with the size of the collection, but at a rate constrained by the size of the controlled vocabulary and the indexing policy. For systems not based on exact match retrieval engines, it seems reasonable to expand the notion of query to include extensive descriptive text since inclusion of words in a query need not exclude documents.

Thus, more access points leads to greater recall, which in turn requires more filtering. This is not necessarily bad if good tools for browsing and filtering are available once a first pass through the database has been made with word-matching probes. Given the nature of human language and the problems of subject access, a general strategy seems prudent: use general (gross) queries/probes to identify a neighborhood of interest and then browse and filter. This strategy implies that system design and development support both parts of this approach.

Human nature.

Human beings revel in diversity. We appreciate alternative expressions for ideas and vary our behaviors to gain new experience. It may be argued that this is so because so much of our life is filled with redundancy, but nonetheless, variety is the spice of life. Thus, the most efficient action is not always the most satisfying, and easier is not always better. Cooking from scratch, growing our own vegetables, and repairing our own products may in some cases yield superior results, but these actions are usually motivated by the satisfaction gained from the process itself. One result of this characteristic is that we sometimes purposefully choose less efficient and less effective means to accomplish tasks. This very human characteristic is in direct opposition to the principles of science and management. Although we tend to aim at optimal processes most of the time, human nature admits suboptimal or counterproductive exceptions.

Human-computer interaction design often aims at optimality. It assumes that people always want to be more efficient in their work and that logical procedures are either superior to or coincident with natural procedures. These assumptions underlie much of our work in subtle ways. We aim to develop organizational schemes that minimize storage requirements and access time, and maximize fidelity of representation. Likewise, we aim to develop interface mechanisms that minimize physical effort and maximize productive outputs. Optimal design may, however, be neither functional nor successful for human activity. Although many of the behaviors aim at reducing monotony, seeking alternative sources of information and reconstructing procedures rather than retrieving them (e.g, seldom used mathematical formulas or recipes) reiterates our basic understanding of principles and reaffirms our self-confidence.

Consider the metric system which is obviously superior to the English system of measurement with respect to logical organization, extensional power, memory load, and learnability. The degree Celsius is carefully mapped to two critical physical points (transition states of water) as well as to the decimal numeration system. However, this system seems inferior to the Fahrenheit system for two reasons. First, in many parts of the earth, temperatures for large portions of the year are below freezing, thus requiring negative values to be written and spoken. Second, the Celsius unit is almost twice as large (1.8 times as large) as the Fahrenheit unit which is a discernable amount of heat for the human system. Thus, although the system is optimized according to logic, it is somewhat disassociated from human needs and conditions. Metric units of length are even more obviously removed from human-centeredness than inches and feet that derived directly from the human condition.

If we examine interface theory and design it is easy to see the influence of optimization assumptions. Designs that minimize movement may in fact short circuit mutually reinforcing or pleasurable interactions between physical and mental activities. Designs that emphasize regularity and repetition may make tasks boring and performance sloppy. Airline pilots may override automatic landing systems to keep their jobs interesting and their skills sharp, clerks may vary sequences of actions to minimize monotony and drivers take alternative routes to experience new scenes. If people do not always want to work optimally and some of our physiological and psychological characteristics do not map directly onto logical data structures and procedures, what can designers do to accommodate humanism? Let me be clear that I do not advocate abandoning systematic design based on task analyses. In fact, humanism provides a basis for user-selectable and adaptable interfaces. What may allow information seeking in electronic environments to evolve according to human needs and characteristics is to consider design an art that admits variation and even playfulness. Certainly, we should strive to create systems that users can alter at will to accommodate those times they wish to abandon efficiency and work for fun.

EVOLUTION AND MUTATION

The changes in information seeking that have occurred as a result of electronic environments are a part of larger evolutionary process. These changes will be refined and extended and new developments will emerge subject to the constraints discussed above. Information seekers must acquire new skills for using technology and extend their personal information infrastructures with new mental models for specific systems. More importantly, electronic environments change our expectations about information seeking--changes that range from the optimism of users who blithely enter natural language queries because they expect machine intelligence, to the reactionary pessimism of those who refuse to use systems on grounds of losing personal service and human interaction. Thus, the central factor in the information-seeking framework, the **information seeker**, changes and adapts to new environments. The other factors are affected as well. Information **tasks** are influenced in so far as users consciously take advantage of better system vocabularies and interfaces when mapping their mental articulations of the problem onto queries and probes. Tasks may also be changed as a result of users considering amounts, types, or availabilities of information accessible in electronic form. Information-seeking tasks that have been avoided or executed at minimal levels using manual systems are more readily expected and accepted and more broadly executed in electronic environments. The **information system** is most obviously changed since the representations and mechanisms are dynamic, typically broader, and always physically distinct from manual environments. **Domains** may also change due to electronic environments, for example, fields that progress through scientific visualizations that yield new theory (e.g., astrophysics, molecular chemistry, meteorology, etc). It is possible that medical research will change dramatically as a result of the development of databases of the human genome. Clinical research may, for example, yield to searches through genetic databases (Mathison, personal communication). In the humanities, the creators of Perseus argue that the availability of the textual and graphic corpus may lead to more integration among literature, art, archaeology, and philosophy. The information **setting** is also changed by technology, since information seekers can work from home or office, and work with machines rather than paper. Finally, **outcomes** are changed by electronic environments since there are often more results to examine, there are better tools for information extraction, and electronic environments often lead to more iterations during information seeking.

Chapter 8 Notes.

1. A ten-million volume collection (most large academic libraries have a few million volumes) of 150,000 word books (this book has about 80,000 words) at a generous 7 characters per word average, yields about 8.5 terabytes.

2. This point should not be underestimated. It is one thing to collect and store huge volumes of data, quite another to process and use it. For example, without parallel processing, it would take 25 years to load and process the 115 terabytes of GOES data currently archived on 27,000 three-quarter inch video tapes!

3. Some school libraries have addressed this problem by marking serial titles that are available in the local collection.

4. It is interesting to observe the steps of system evolution in this regard. We are progressing from having huge printed volumes of subject headings placed near to OPACs, to putting the subject headings online as a separate file or function, to integrating them as a feature of the interface.