Chapter 9. Future Directions and Conclusion

Evolution proceeds in many waves, some brief by human temporal sensibilities and some cycling over centuries. Some changes in information seeking take place before technological investments are fully amortized (e.g., the latest CPU or software upgrade brings with it access to new information resources) and some take place over careers as strategies and patterns of use learned in school evolve based on new sources and tools. This final chapter examines one long-term change that computing technology brings to cognition in general and information seeking in particular, considers how different domains interact to influence the evolution of information seeking, and concludes with some provocations about what types of systems we should strive to build.

AMPLIFICATION AND AUGMENTATION

Applying computational power to information problems has been a research and design goal from the first days of computing. The dreams of language translation and cybernetic assistants have given way to dreams of artificial realities and intelligent agents, but our fascination with the manipulation of symbolic data and interactivity remain driving forces behind much of the research in artificial intelligence and engineering. One way to consider how computation may be applied to information problems is to examine how it may be applied to amplify and to augment intellect. Engelbart (1963) provided an early explication of how computing could be applied to amplify and augment the intellect and many of the developments he envisioned over 30 years ago have been fulfilled.

Amplification connotes an increase in an existing value or capability, while augmentation connotes the addition of a new value or capability. Electronic technology allows us to reach more people during information seeking and to scan or search more sources. Technology amplifies information seeking when it provides mechanical advantages for some of the information-seeking subprocesses, which in turn allows reallocations of time and cognitive load. As mechanical advantage grows, it begins to change what is possible--a form of augmentation. Determining when there is enough amplification to enable new capabilities is a central problem in many fields (e.g., when velocity overcomes the force of gravity; when sufficient political dissatisfaction accumulates to force a parliamentary election, when multiple images become motion pictures, etc.). For information science, determining when speed and quantity of access enables new types of questions to be addressed is an important issue. One indicator that amplification has led to augmentation is in how our expectations change; when we come to expect as commonplace those things that were impossible or difficult beforehand. In turn, our expectations determine our actions, and the manual actions we amplified with technology eventually lead to entirely new actions. This chain of changes is one form of progress and is repeated for different technologies and different generations as part of the evolutionary process.

Least this argument be overgeneralized, an important distinction must be made between changes in behavior and changes in thought. There is little evidence that basic cognitive and affective activity has changed due to any of the technological changes of the centuries, although many argue that television and video games have fundamentally altered attention spans. What has changed are the objects of thought and external tools for representing and transmitting the products of thought. Technological amplification leads to time savings that may lead to more thought and creativity (augmentation) or these savings may simply be filled with other, similar work--a menial productivity gain. One form of Parkinson's law tells us that jobs expand to fill the time available and most of the productivity gains that technology provide suggest amplifications of behavior rather than augmentations of thought. An often-debated illustration of this distinction is the question of whether word-processing tools have improved the quality of writing or simply made additional time for writers to perform clerical tasks and write in greater volume.

From an information seeking perspective, an augmentation is indicated when the types of questions change. If factual access is less behaviorally demanding, then teachers, researchers, and workers can change assignments, problem focus, and tasks. A key decision is whether the diminished demands lead to more fact retrieval (amplification) or to interpretive information seeking. Some instructors who used Perseus in their teaching changed the types of assignments they gave to students so that students were engaged in exploring primary materials and thinking critically about them rather than studying textbook explications of what scholars wrote about those materials. This was an augmentation of the course, since it enabled new types of activity. Some students blossomed with the freedom to discover and invent their own theories, some floundered about without much effect, and still others complained that they missed the safety of scholarly interpretations. Clearly, these assignments took the place of traditional assignments and in many ways were less time-efficient.

Another way to address the distinction between behavior and thought is to consider specific tasks, the larger activity or job in which those tasks are embedded, and general intellectual activity required for the job. When technology is used to amplify a specific task (e.g., get results faster, reach more people), the result is a gain in available time or a reserve of effort. Time saved by the amplification can be used in different ways: for leisure activity, to perform more similar tasks, or to enable new types of tasks to be undertaken. When more similar tasks are performed, a simple gain in productivity results that may be considered an amplification of the job but have no effect on general intellectual activity. When new tasks are undertaken as a result of time savings, the job is augmented and intellectual activity may also be affected. For example, automation of serials ordering in a library can save the time usually required to manually fill out and mail order forms. Time savings in this case may allow more attention to evaluation and selection, and require different levels and amounts of intellectual activity. When amplification leads to a savings of effort rather than time, productivity gains may not reflect more throughput but yield higher quality products. For example, if an electronic search yields many more documents, more time may be required to examine those documents, but overall quality of solutions may be better. These examples illustrate a plausible chain of inferences about how amplification of tasks may lead to augmentation of the larger activity, and possibly to augmentation of intellectual activity. Whether these inferences obtain is dependent on individual wills and institutional policies.

Interfaces are amplifications since they enable people to easily and effectively map tasks onto information resources. This book has argued that design should amplify human behavior rather than augment it directly. When it comes to human performance, augmentation ultimately flows from amplification rather than from some external intervention. If we ever learn to be telepathic it will come from learning about human physiology rather than from the invention of some device. Amplification leads to augmentation over long evolutionary periods due in large part to the constraints of the physical and cultural environment. Humans evolve rather than transform and systems that support intellectual activity should amplify intellectual activity rather than aim to directly transform it.

COMMUNITIES OF PERSPECTIVE AND INTERDISCIPLINARITY

Because information seeking is a generic cognitive activity, different communities develop views and strategies that are most useful for the knowledge and problems specific to their fields of interest. Although there has always been commonality between fields such as psychology, education, and library and information science, the advent of electronic information systems has broadened the overlap, extended the commonality to other fields, and led to increased collaboration and interdisciplinarity. This book is aimed at communities interesting in human-computer interaction and information science. These communities, in turn, draw theoretical principles and active participants from the fields of computer science and engineering, education, communications, psychology, philosophy, sociology, and library and information science. Each of these disciplines is concerned with information seeking and has developed particular views, language, and techniques. Rather than a Tower of Babel, there is strength in this diversity of views but researchers and practitioners must extend their reach beyond the comfortable confines of their discipline to cognate fields and perspectives.

Research results have demonstrated that information seeking depends on many interacting factors and is evolving in conjunction with developments in electronic technologies. Although much of the research on information seeking has focused on cognitive processes in the information seeker, much more remains to be discovered about how people formulate information problems, strategize plans, express those formulations, reflect on the results, extract and use information, and monitor the entire process. Little work has been done related to the affective factors that influence information seeking and this seems to be a promising area for research. Although there has been considerable research on the physiological processes related to information seeking in manual environments, we need basic evidence on what are the physiological limits of human capabilities for scanning, recognizing, and browsing in electronic environments. Thus, there are needs for research on the cognitive, affective, and physiological aspects of the human factors of information seeking. These problems invite multidisciplinary teams of psychologists, information scientists and sociologists.

Another research area focuses on the search system. Many engineering problems related to computational speed to process huge amounts of data on-the-fly, high-quality display, and novel input and output devices remain to be solved. More central to the concerns of this book, interface design and development have many challenges, including: customizable interfaces for diverse user communities, new mechanisms for browsing and managing multiple views, integrating analytical and browsing strategies in a common interface, rich and smoothly integrated representations for information objects at different levels of granularity, and balancing user control with system help and documentation. These challenges invite interdisciplinary teams of engineers, computer scientists, and information scientists. Since information seeking performance is also determined by the underlying information structures of search systems, computer scientists and information scientists must develop more powerful and more flexible data structures and indexes. Organizations that provide alternative views that are preprocessed must be augmented by structures that allow on-the-fly views to be extracted according to the immediate and evolving needs of information seekers.

The results of research thus far and the directions for the future have implications for practitioners. Designers of electronic search systems have a huge marketplace for their work and can best succeed by adopting a user-centered design philosophy and attending to the possible interactions among the information-seeking factors. In addition to task analysis, designers must know their user population and conduct formative evaluations. Just as most programming is maintenance rather than original work, interface work will increasingly aim at improving existing interfaces that have large installed bases. Thus, software engineering principles of reusability and incremental improvement should be adopted. Designers and developers should consider ways that browsing strategies can be supported while not losing the power and precision that analytical strategies provide.

Information specialists are perhaps most challenged by the evolution of information seeking. Increasingly, their roles are shifting to training and assisting end users who conduct their own searches rather than conducting searches for them. Librarians and information specialists are engaging in more ongoing collaboration with end users rather than serving as modular consultants on projects. These professionals have always been concerned with the organization and presentation of information and these skills and experiences will increasingly be adapted to electronic environments. Most importantly, information specialists should be engaged in the evaluation process. Information in many forms and in huge quantities must not only be organized for access but also judged for accuracy and value. Information specialists can coordinate the domain specialists who make such judgments and be sure that evaluative information is included at all levels of representation starting with the bibliographic record. Additionally, information specialists in the publishing industry are challenged to organize and disseminate digital multimedia representations in ways that provide fair return to creators yet insure equitable access to all.

WHAT KINDS OF INFORMATION ENVIRONMENTS DO WE WANT?

Given that electronic technology will play a role in most cases of information seeking in the future but has not yet reached levels of maturity that bring stabilization and predictable growth, it is worth speculating on how we envision information seeking in the future. Several technological trends are touted as candidates for improving the state of affairs.

Natural language processing has developed through several stages from early machine translation approaches based on brute force algorithms to knowledge-based approaches that depend on huge amounts of organized information and sets of inferencing rules. Whether computers can "understand" human language is an issue for philosophers, what is clear is that computers can recognize speech or typed text that adheres to regular patterns and has as object the execution of some well-defined task. As work on natural language processing progresses, the ranges of patterns and tasks will certainly grow and interfaces that apply human language will be more common. As is the case with all systems that support information seeking, people must still be able to articulate their information problem, make decisions about progress, and interpret results.

Intelligent agents have generated considerable interest, possibly because of the naive notion that we can all use personal secretaries or assistants in our professional and personal lives. Agents are reminiscent of batch processing, where tasks are defined and the user goes on to another problem while the system executes the task. Two problems with agents for information seeking are apparent. First, the information seeker must articulate the task to the agent. This entails specifying where, what, and how the agent should search. Additionally, it requires that information seekers manage their agents--a requirement that itself could become time-consuming. Second, it has been argued in this book that information seeking is a process and simply being involved with the input and output robs the information seeker of significant parts of the process. It is easy to imagine sending agents off to do simple retrieval tasks, but it makes no more sense to believe that people will abdicate the experience of complex information seeking and learning to agents than it does to believe they would send their dog to the theater to see a play.

Another technology that generates considerable interest is virtual reality (telepresence). Visions of gliding through the bookshelves of virtual libraries and picking up animated volumes of information make for good conversation, but what real advantages can virtual reality offer? Information seeking is most associated with non-fiction, with representations for abstractions related to reality. For virtual reality to be useful, it is necessary for designers to somehow represent ideas and concepts as objects that can be observed and manipulated. This may be possible for spreadsheet values or database entries but moving in and out of spaces of concepts and ideas requires that such spaces be defined and filled with appropriate information sources. This is the essential problem of classification systems (e.g., Dewey Decimal System, the Colon Classification System, etc.); the problems of categorization such systems encounter are intellectual and interpretive in nature and any virtual representation is only as good as the underlying categorizations. Virtual reality seems promising for managing things but it is unclear how it can help people manage words and ideas. Virtual reality seems most appropriate to entertainment based on fictional contexts or to training simulations for complex systems (from which it developed).

Another technological trend that offers some interesting possibilities for information seeking is ubiquitous computing, in effect the aggregate advantages of having interconnected computers everywhere. Computers on the person (ranging from "Dick Tracey" communication watches to wearable robots) unite with computers in the home and workplace to provide constant access and control capabilities. Beyond the obvious possibilities of using commuting time to access and use remote information, having computational devices in the world around us gives new levels of control. If we consider putting computers in books and other information sources rather than simply aiming at putting books on computers, we may be able to invite information more readily to come to us rather than having to go find it.

In addition to looking at specific technological trends it may be instructive to consider global functionality. Do we want uniform information systems? Should everyone in the world be given a standardized device that enables uniform training and supports equitable usage? Although the final results from competitiveness in the telephone industries of the world are not yet in, there clearly seem to be some advantages to diversity of systems and services. A more idealized functionality is what might be called information alchemy. Given a potentially relevant information item, systems should be able to re-represent it in a different form that more readily suits the needs of the information seeker. In the simplest case, a data set should be displayable in tabular or graphical forms. In the extreme, a text should be representable as a video. Re-representation is made possible by electronic environments and many information-seeking innovations will come as we move from the simple re-representations toward the impossible extremes.

One way to encourage divergent thinking about possibilities is to consider some scenarios that embed various technological trends within problem contexts. The following three scenarios are meant to provoke thought about possible directions for future systems.

Scenario One: Multimedia knowledge bases.

Deanna is a first-year engineering student assigned to a team that must design and build a windmill as a semester project. Cost constraints are provided, the model must be built and tested using reliable metrics, and a comprehensive written report that defends the procedure with literature and practice must be delivered. As part of the first group discussion, each member agrees to spend two weeks learning as much about windmills as possible before assigning specific tasks to individuals. Deanna accesses The Net from her dorm room and verbally describes her information needs to the system, at times reading phrases and sentences from the assignment provided by the instructor. A series of video descriptions appear. She does not even consider the virtual world option, having long since decided that simulated experiences were best left to entertainment purposes. To determine which video to use she chooses to see 48 frames per second video clip summaries (she has learned through experience that 50% increases in display still allows her to extract gist from motion images--she envies her sister's ability to comprehend 75% increases) rather than view the written summaries or hear the verbal summaries of each. Since she said she is looking for overview information at this time, the system presents 100 video summaries ranked according to statistical and knowledge-based retrieval analyses of her verbal problem statement. The fourth clip looks interesting and includes some spectacular views of the Utah desert area she plans to explore next summer. Her gesture freezes the summary window and begins the 30 minute presentation on windmills throughout history narrated by a prominent Japanese professor of materials science. As the video progresses, Deanna cuts and pastes single frames and short sequences into her notebook, including textual transcripts in some cases. About ten minutes into the video, she freezes the presentation and goes back to the summary window to scan through several more possible choices. After viewing one complete video and speeding through several more, she begins to focus on the tradeoffs between number of blades and production tolerances. Requesting blueprints for a two-blade optimal windmill for moderate wind conditions and for the traditional prairie design, she runs simulations under different wind speeds to assure herself that the two-blade design is superior. Fortunately, she noted that the narrator had commented on how critical blade balance was in the two-blade design and on the high costs of ceramic blades. She wonders what kinds of cost-performance tradeoffs will occur given the group's inexperience with manufacturing processes and their severe cost constraints. She types this problem (she found long ago that she can type as fast as she can talk), attaches it to her notes and copies the rest of the group to get their thoughts on whether they should aim for an optimal design they may not be able to implement or a more practical design.

Scenario Two: Intelligent agents.

Brian has 15 years experience as a clinical psychologist in a state-run long-term care facility for the elderly and also has a thriving private practice. Because government services are increasingly contracted out to private enterprise, Brian has begun to consider opening a for-profit long-term facility. He has first-hand experience with what services are needed and has many colleagues who may be interested in joining his venture. He needs information about the administrative aspects of the concept before he can begin serious discussions with others. Brian sits down at his workstation and begins to compose intelligent agents that he will send into the Global Web. Although he does not have the latest agent-construction set, he has good experience using and confidence in Knowboty Better (Version 5.8.1, trademark Megasmart Inc.). Brian defines an agent to gather information on local and state regulations for medical facilities, specifying the finest grain of detail (he wants regulations on all aspects of buildings and services) but narrowest set of sources (he only wants regulations for a single state and a few specific counties). He defines another agent to explore financial sources for investment costs, profit data, and competition in the long-term care field, setting broad parameters for sources and overview information (he knows he will eventually refine this agent to seek more specific data once he has gained a sense of the financial aspects). He requires this agent to report back daily and to include public domain simulation models he can use for analyzing the data. He configures another agent to locate and organize coverage data for the various public and private health insurance options, specifying weekly reports. Another agent is defined to examine availability of human resources in the region and typical credentials and salaries for physicians, nurses, attendants, social workers, and other health care workers. He suggests several professional jobline sources with which he is familiar and allows flexibility for the agent to consult others with high-similarity profile coefficients (including the newspaper want ads). Other specific agents are similarly constructed for topics such as availability of buildings in the region, tax codes, and venture capital sources. A global agent is also constructed to gather medical and psychological case studies conducted in long-term care facilities. This agent's parameters are set to report back every other day and deposit cases in a database of psychological cases Brian has constructed as part of his professional growth over the years (he views this as a sort of hedge since even if he eventually decides not to develop a formal prospectus for the venture, he will have augmented his psychological database with some physiological cases that may help him in his work).

Scenario Three: Implants, ubiquitous computing, and human-machine symbiosis.

Suzanne has a busy medical practice in a large metropolitan area. When she arrives at her office, she notes that the day wall displays today's appointments, most of which involve routine checkups or well-defined symptoms, but eight of them glow softly to suggest that some special preparations be made. The first special case is a patient she has not seen in two years, a middle-aged man with little medical history who is coming is as a result of persistent headaches and mild fevers for the past 10 days. Suzanne selects one of the hundreds of implant modules displayed on the info wall and activates the radio link between the wall and her knowplant. Her knowplant (Real Intelligence Inc.) was recently upgraded to provide better visual/kinesthetic fidelity and coordination, although she wishes she had invested the extra money to get the newly developed olfactory link. In the milliseconds it takes for the module to come inmind (beyond online) she gasps at the visual/auditory burst, a sensation she has never quite gotten used to in her years of using her various implants. Although thinking about headache and fever will yield sensations and visual/auditory images of the latest causal probability diagrams with accompanying case studies, Suzanne verbalizes the words as well. The Symbiosis Society has long debated whether multiple channel inputs improve the focus or the vividity of memories but she has always found it reassuring to verbalize while thinking. As specific cases fleet through her mind, she turns her interest to possible diagnostic tests. Various instruments and monitors in her examination room snap to attention as she considers the data collection strategies she may want to use during her examination later that day. The various instruments are alerted by Suzanne's implant through signals sent to their internal computers and subsequently updated from the patient medical record by the info wall. Suzanne recalls her mentor from medical school who told stories about searching huge bibliographic files just to locate paper journal articles that were then obtained through interlibrary loan; now what was the name of that system? It never ceased to amaze her that simple fact retrieval was more difficult with knowplants since their organizations were conceptual in nature, (top down from concepts to cases) rather than organized by discrete tokens like those retrieval systems of old. As the first patient of the day arrives, it occurs to Suzanne that her patients believe they are coming to her office but in many ways they are coming into her mind and enveloped by her augmented expertise disguised as an office.

Each of these scenarios offers some appeal and some repulsion. Although cast in positive contexts, each scenario could as easily have presented the same technological perspective in horrific settings. It seems certain that aspects of each of these scenarios will come to pass, with the order of presentation likely correlating with passage of time. Certainly, most of the technical components of scenario one are available today if cost constraints and the dilemma of technology/database push-pull (if there was an installed base of hardware, the programming would come and vice versa) are ignored. Scenario two represents an active area of research and speculation and surely today's ability to send queries to multiple databases on a "canned" user profile basis will continue to grow in sophistication. A major problem here is "agent management"; controlling a group of agents itself requires time and effort, let alone making sense out of and integrating the fruits of their searches. Scenario three is the least technically feasible, but research in monitoring and controlling electromagnetic and electrical activity in the brain continues to progress toward mapping and understanding how the brain works. Moreover, the trends toward installing computing power in many devices rather than a single workstation is strong, positive, and irreversible. In fact, we need attention on putting computers in books rather that putting books on computers. The main problem here of course is not the technology but failure to distinguish brain and mind. We can conceive of a brain that contains all the external representations of knowledge in the world, but not a mind that could survive without learning and interpretation.

More specifically, these scenarios do not obviate the importance of the information seeking process. Information problems must be recognized, accepted, and defined. Although recognition and definition may be aided by external factors, acceptance is a strictly human factor. Moreover, recognition and definition must be driven by conscious attention and thought, and consciousness is the antithesis of machinery. Information problems must be articulated and search systems selected. These subprocesses require mapping mental concepts to words, icons, or other physically represented tokens. System selection requires knowledge about alternatives and evaluative judgments of coverage and value. Evaluation and selection are perhaps the most critical elements of human information-seeking activity and are applied during the subprocesses of system selection and examination of results. In all the scenarios above, the information seeker makes judgments about the possible relevance of high-level representations such as video summaries or memory modules. Moreover, relevance judgments for specific primary information related to the problem must take into account applicability, accuracy, and expected value. These decisions in turn determine what is extracted and eventually used in solving the information problem. In sum, the technology may evolve beyond anything we can now imagine, but information seekers will always be required to think, make inferences and decisions, and develop confidence in these processes.

CONCLUSION

The essential aim of information seeking is to get relevant information into one's head and either use it in conjunction with known information to take some action or integrate it into the knowledge base. This is accomplished by coordinating information-seeking factors in systematic and heuristic ways. Our personal information infrastructures are central to this process. Domain knowledge helps us to determine where to look and what to look for; information seeking skills help us to formulate queries and browse; system knowledge allows us to manipulate the many devices that provide access to the various representations available. Search systems not only deliver information, but provide structure and format that guides and influences search. A critical need is for human-computer interaction research to address how electronic systems can enhance and go beyond the delivery and structuring techniques available in manual environments. Domains of knowledge organize themselves to distinguish themselves from other domains. These organizations and protocols guide information seeking for those familiar with the domain but systems that are used by domain novices must illustrate and make explicit such features.

There can be no doubt that we are immersed in a set of complex relationships with the environment. The things we do and the things we choose to think about are influenced by the world around us. Likewise, as part of the environment, we influence the world--sometimes in devastating ways. People are incredibly adaptable to positive as well as adverse conditions and also adapt the world to their needs. In the case of information environments we have adapted to systems, collections, and organizations that have been put together in either haphazard ways or for the sake of efficiencies of scale. A more balanced, ecological and sustainable view of information seeking in electronic environments aims to design systems that amplify human capabilities and propensities so that the augmentations that ultimately result will be positive and natural rather than sophisticated workarounds that we pass on to future generations of information seekers.

Our personal information infrastructures are constantly developing and changing throughout our lives. Systems designed principally for the convenience of the designer or the institution rather than the end user impede productive and satisfying work and inhibit the continued development of personal information infrastructures. What has been argued in this book is design based on taking advantage of natural human capabilities and propensities rather than systems that magically or transparently think for users. This is particularly important for information seekers since information seeking is primarily an intellectual rather than a physical activity. We may like the thought of machines that find the information we need for us, and in fact, we can observe systems that retrieve well-defined facts that we may need at any given time. What we cannot image and what we will not admit are machines that think for us. Somewhere in between is where most of information seeking falls. Information seeking is thinking in that most of the time we are not quite sure what we need--we are not quite sure what is the information problem--and it is the seeking itself that illuminates, informs, and assists us in defining, growing, learning, and succeeding. Directly hard-wiring one's brain to a world encyclopedia database may ultimately facilitate more rapid associations and more broad-based associations, but ultimately it is our personal struggles with the problems, concepts, and abstractions of information that not only define intellectual tasks but define what we are as human beings.

Two principles obtain from this point of view. First, we should design systems that amplify and enhance natural capabilities. Second, we should pay more attention to the information-seeking process and the interactions among the information seeking factors rather than to technology itself. An ecological point of view that bases design on how the different components interact with and influence one another is what is needed. The information-seeking process has become much more integrated due to electronic environments, much more fluid and more parallel, however, most of the tools and techniques that have been developed focus on the query formulation and examination subprocesses. These are clearly needed, but what is more critical is attention to the problems of acceptance, definition, extraction, and use, and in fact, integrating the entire information-seeking process into the larger tasks of learning, working, and planning.