HUMAN FACTORS OF INTERACTIVE SOFTWARE

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Abstract: There is intense interest about human factors issues in interactive computer systems for life-critical applications, industrial/commercial uses, and personal computing in the office or home. Primary design goals include proper functionality, adequate reliability, suitable cost, and adherence to schedule. Measurable human factors issues include time to learn, speed of performance, rate of errors, subjective satisfaction, and retention over time. Specific human factors acceptance tests are described as a natural complement to hardware and software acceptance tests. Project management ideas, information resources, and potential research directions are presented.

1. INTRODUCTION

Civilization is a product of the tools and processes created to serve people. Neolithic stone tools for hunting and construction, Medieval weapons and armor, Gutenberg's movable type for printing, Daguerre's photographic processes, the automobile, and television are but a few of the dramatic inventions which have shaped the evolution of history. The first products were crude, but each technology was eventually refined to accommodate human needs.

New technologies are often difficult to use, but provide remarkable, almost supernatural, powers to those who master them. Then the technology becomes more reliable and widely used. Eventually it becomes integrated into common experience, so that its absence is a severe loss.

Computer systems are a new technology in the first stages of refinement and dissemination. The opportunities for designers and entrepreneurs are substantial, but only a fraction of the potential usage has been explored. Like early photography or automobiles, computers are available only to those who devote extensive effort in mastering the technology. Harnessing the computer's power is a task for designers who understand the technology and are sensitive to human capacities and needs.

Human performance in the use of computer and information systems will be a rapidly expanding research topic in the next decades. This interdisciplinary topic combines the experimental methods and intellectual framework of cognitive psychology with the powerful and widely used tools developed from computer science.

Closely related fields include education where computers are increasingly used in programs ranging from elementary school through professional skills development. The theory and measurement techniques of educational psychology are applicable to studying the learning process in novice computer users. Business system design and management decision making are endeavors which are being increasingly shaped by the nature of the computer facilities. Library and information services are also dramatically influenced by the availability of computer-based systems.

In these disciplines and certainly others, there is growing interest in the human factors issues of computer use with systems such as:

- text editors
- electronic mail and computer conferencing
- videotext/viewdata
- programming environments and tools
- bibliographic retrieval
- information and database search
- personal and home computing
- computer-based education
- commercial systems such as inventory, personnel, and reservations
- decision support systems
- electric utility and air traffic control
- entertainment.

Design issues include novice vs. expert differences, command language vs. menu selection, graphical approaches, speech input and output, response time and display rates, novel input and output devices, keyboard design, on-line assistance, tutorials, and consultants, documentation, training, evaluation methods, experimental techniques, cognitive models of user behavior, organizational impact, and social issues.

2. PRIMARY DESIGN GOALS

Every interactive system designer wants to build a high quality system that is admired by colleagues, celebrated by users, circulated widely, and frequently imitated. Appreciation comes, not from flamboyant promises or stylish advertising brochures, but from inherent quality features which are arrived at by thoughtful planning, a sensitivity to user needs, careful attention to detail in design and development, and diligent testing. Multiple design alternatives are raised for consideration and the leading contenders subjected to further development and testing. Evaluation of designs refines the understanding of appropriateness for each choice.

Successful designers go beyond the vague notion of "user friendliness" and probe deeper than a checklist of subjective guidelines. They must have a thorough understanding of the diverse community of users and the tasks that must be accomplished. The first step is to ascertain the necessary functionality - what tasks and subtasks must be carried out. The frequent tasks are easy to determine, but the occasional tasks, the exceptional tasks for emergency conditions, and the repair tasks to cope with errors in use of the system are more difficult to discover. Task analysis is central, because systems with inadequate functionality frustrate the user and are often rejected or underutilized. If the functionality is inadequate it doesn't matter how well the human interface is designed. Excessive functionality is also a danger, and probably the more common mistake of designers, because the clutter and complexity make implementation, maintenance, learning, and usage more difficult.

The second step is ensuring proper system reliability. The software architecture and hardware support must ensure high availability, ease of maintenance, and correct performance. If the system is not functioning or introduces errors, then it doesn't matter how well the human interface is designed. Attention must also be paid to ensuring privacy, security, and information integrity. Protection must be provided from unwarranted access, inadvertent destruction of data, or malicious tampering.

The third step is to plan carefully to be on schedule and within budget. Delayed delivery or cost overruns can threaten a system because the confrontive political atmosphere in a company or the competitive market environment contain potentially overwhelming forces. If an in-house system is late then other projects are effected and the disruption may cause managers to choose an alternative. If a commercial system is too costly, customer resistance may emerge to prevent widespread acceptance which allows competitors to capture the market.

When these three steps - identifying adequate functionality, ensuring system reliability, and scheduling and budgeting - are taken care of, the human factors aspects of the design can be considered.

3. HUMAN FACTORS DESIGN GOALS

If adequate functionality has been chosen, reliability is ensured, and schedule plus budgetary planning is complete, then attention can be focussed on the human factors issues. The multiple design alternatives must be evaluated for specific user communities and for specific benchmark sets of tasks. A clever design for one community of users may be inappropriate for another community. An efficient design for one class of tasks may be inefficient for another class.

The Library of Congress Experience

The relativity of design played a central role in the evolution of information services at the Library of Congress. Two of the major uses of computer systems were for cataloging new books and for searching the on-line book catalog. Separate systems for these tasks were created which optimized the design for one task and made the complementary task difficult. It would be impossible to say which was better, because they were both fine systems, but serving different needs. It would be like asking whether the New York Philharmonic Orchestra was better than the New York Yankees baseball team.

The bibliographic search system, SCORPIO, was very successfully used by the staffs of the Library of Congress, the Congressional Research Service (CRS), and the Senate and House of Representatives. They could do bibliographic searching, and used the same system to locate and read CRS reports, to view events recorded in the bill status system, and much more. The professional staff members took a three to six hour training course and then could use terminals in their office where more experienced colleagues could help out with the problems and where adequate consultants were usually available.

Then in January 1981, the Library of Congress stopped entering new book information in the card catalogs, thus requiring the general public to use one of the eighteen terminals in the main reading room to locate the new books. For even a computer/knowledgeable individual, learning to use the commands, understanding the cataloging rules, and formulating a search strategy would be a challenging task. The reference librarians claimed that they could teach a willing adult the basic features in fifteen minutes, but fifteen minutes per patron would overwhelm the staff and more importantly, most people are not interested in investing even fifteen minutes in learning to use a computer system. The library patron has work to do and often perceives the computer as an intrusion or interference with their work. The SCORPIO system which worked so well for one community of users, was improperly designed for this new community.

The system designers revised the on-line messages to provide more supportive and constructive feedback, offered extensive on-line tutorial material, and began to explore the use of menu selection approaches for the novice users. In short, a new community of users demanded substantial redesign of the human interface.

Measurable human factors issues

Once a determination has been made of the user community and the benchmark set of tasks, then the human factors issues can be examined. Again and again I returned to these five measurable human factors issues:

- time to learn. How long does it take for typical members of the target community to learn how to use the task relevant set of commands.

- speed of performance. How long does it take to carry out the benchmark set of task?
- rate of errors. How many and what kind of errors are made in carrying out the benchmark set of tasks? Although time to make and correct errors might be incorporated into the speed of performance, error making is such a critical component of system usage that it deserves extensive study.
- subjective satisfaction. How well did users like using aspects of the system? This can be ascertained by interview or written surveys which include satisfaction scales and space for free form comments.
- retention over time. How well do users maintain their knowledge after an hour, day, or week? Retention may be closely linked to ease of learning, frequency of use plays an important role.

Every designer would like to succeed in every issue, but there are often forced trade-offs. If lengthy learning is permitted, then task performance speed may be reduced. If rate of errors is to be kept extremely low, then speed of performance may have to be sacrificed. In some applications, subjective satisfaction may be the key determinant of success, while in others short learning times or rapid performance may be paramount. Project managers and designers must be aware of the trade-offs and make their choices explicit and public. Requirements documents and marketing brochures should make clear which issues are primary.

4. HUMAN FACTORS ACCEPTANCE TEST

Once the decision about the relative importance of each of the human factors issues has been made, specific measurable objective should be established to guide designers and implementers. The acceptance test plan for a system should be included in the requirements document and should be written before the design is made. Hardware and software test plans are regularly included in requirements documents; extending the principle to human interface development is natural.

The requirements document for a word processing system might include this acceptance test:

> The subjects will be 35 secretaries hired from an employment agency with no word processing experience, but typing skills in the 35-50 words per minute range. They will be given 45 minutes of training on the basic features. Then at least 30 of the 35 secretaries should be able to complete 80 percent of the typing and editing tasks in the enclosed benchmark test correctly within 30 minutes.

Another testable requirement for the same system might be:

> After four half days of regular use of the system, 25 out of these 35 secretaries should be able to carry out the advanced editing tasks in the second benchmark test within 20 minutes while making fewer than 6 errors.

This second acceptance test captures performance after regular use. The choice of the benchmark tests is critical and highly system dependent. The test materials and procedures must also be refined by pilot testing prior to use.

A third item in the acceptance test plan might focus on retention:

> After two weeks, at least 15 of the test subjects should be recalled and be required to perform the third benchmark test. In 40 minutes at least 10 of the subjects must be able to complete 75 percent of the tasks correctly.

Such performance tests constitute the definition of "user friendly" for this system. By having an explicit definition, both the managers and the designers will have a clearer understanding of the system goals and whether they have succeeded. The presence of a precise acceptance test plan will force greater attention to human factors issues during the design and ensure that pilot studies are run to determine if the project can meet the test plan goals.

In a programming workstation project, the early requirement for performance helped shape the nature of the interface. That requirement was:

> New professional programmer users should be able to sign on, create a short program, and execute it against a stored test data set, without assistance and within 10 minutes.

Specific goals in acceptance tests are useful, but competent test managers will notice and record anecdotal evidence, suggestions from participants, subjective reactions of displeasure or satisfaction, their own comments, and exceptional performance (both good and bad) by individuals. The precision of the acceptance test provides an environment in which unexpected events are most noticeable.

5. MOTIVATIONS FOR HUMAN FACTORS IN DESIGN

The enormous interest in human factors of interactive systems arises from the complementary recognition of how poorly designed many current systems are and from the genuine desire to create elegant systems which effectively serve the users. This increased concern emanates from three primary sources: life-critical systems, industrial/commercial uses, and office, home, and entertainment applications.

Life-critical systems

Life-critical systems include air traffic, nuclear reactor, or power utility control, medical intensive care or surgery, manned spacecraft, police or fire dispatch, and military operations. In these applications high costs are expected, but they should yield high reliability. Lengthy training periods may be acceptable to obtain rapid, error free performance. Subjective satisfaction is less of an issue and retention is obtained by frequent use.

Industrial/commercial uses

Typical industrial/commercial uses include banking, insurance, order entry, inventory management, airline, hotel, or car rental, utility billing, credit card management, and point-of-sales terminals. In these cases, costs shape many judgments; lower cost may be preferred even if there is some sacrifice in reliability. Operator training time is expensive, so ease of learning is important. The trade-offs for speed of performance and error rates are decided by the total cost over the system lifetime. Subjective satisfaction is of modest importance and again retention is obtained by frequent use. Speed of performance becomes central for most of these applications because of the high volume of transactions. Trimming ten percent off of the mean transaction time means ten percent fewer operators, ten percent fewer terminal workstations, and possibly a ten percent reduction in hardware costs. A 1982 study by a leading motel chain reported that a one second reduction in the 150 second mean time per reservation would save $ 40,000 per year.

Office, home, and entertainment applications

The rapid expansion of office, home, and entertainment applications is the third source of interest in human factors. Personal computing applications include word processing, customer bank terminals, video games, educational packages, information retrieval, electronic mail, computer conferencing, and small business management. For these systems ease of learning, low error rates, and subjective satisfaction are paramount because use is frequently discretionary and competition is fierce. If the users can't succeed quickly they will abandon the use of a computer or try a competing package. In cases where use is intermittent, retention is important, so on-line assistance becomes very important.

Choosing the right functionality is difficult; novices are best served by a constrained simple set of actions, but as experience increases so does the desire for more functionality. Layered or level structured designs are one approach to graceful evolution from novice to expert usage. As users gain competence, their desire for more rapid performance and extensive functionality grows. Low cost is important because of lively competition, but extensive design and testing can be amortized over the large number of users.

These three stereotypical classes leave out many applications, but a similar analysis of needs can be performed. The first step in design is to make explicit the goals and metrics of success.

6. MANAGING THE DESIGN PROCESS

In the first decades of computer software development, senior programmers designed text editors, operating system control languages, programming languages, and applications packages for themselves and their peers. Now the user population for office automation, home and personal computing, and point of sales terminals is so vastly different, that the experience and intuition of senior programmers may be inappropriate. Designs must be validated through pilot and acceptance tests which can also provide a finer understanding of user skills and capabilities.

The egocentric style of the past must yield to humility and a genuine desire to accommodate to the user's skills, wishes, and orientation. Designers must seek more direct interaction with the users during the design phase, development process, and throughout the system lifecycle. Corporate marketing departments are aware of these issues and are a source of constructive encouragement. When more than two hundred suppliers provide similar word processing packages, human engineering is vital for product acceptance.

While many organizations maintain a human factors group which is a source of experience and expertise in testing techniques, in some cases, this resource is not used because the group members are not familiar with the application area, are perceived as being outsiders, or must be paid as if they were external consultants. Development projects might be better served if a human factors role were assigned to a team member, or to several members if the project is large. The human factors coordinator for a project would develop the necessary skills for the project and would be more effective in communicating with external human factors professionals when further expertise, references to the literature, or experimental tests were required. This dual strategy balances the needs for centralized expertise and decentralized application. It enables professional growth in the human factors area and in the application domain.

As projects grow in complexity, size, and importance role specialization will emerge, as it has in architectural, aircraft, or book design. Eventually individuals will become highly skilled in specific problems such as dialog management techniques, graphic display algorithms, voice and audio tone design, writing of messages and menus, or on-line tutorial writing. Consultation with graphic artists, book designers, advertising copy writers, instructional text book authors, or movie animation creators may be useful. Perceptive system developers will recognize and employ psychologists for experimental testing, sociologists for evaluating organizational impact, educational psychologists for refining training procedures, and psychiatric social workers for guiding user consultants or customer service personnel.

7. INFORMATION RESOURCES

There is an enormous volume of literature in computer science, psychology, human factors, and other areas which might be relevant, but some sources are especially rich. Two prominent journals which focus on questions of human performance with computers are:

Behavior and Information Technology
International Journal of Man-Machine Studies

Other journals regularly carry articles of interest:

ACM Computing Surveys
Communications of the ACM
Ergonomics
Human Factors
IBM Systems Journal
IEEE Computer
IEEE Transactions on Systems, Man, and Cybernetics
Journal of Applied Psychology.

The Association for Computing Machinery (ACM) has a Special Interest Group on Computer & Human Interaction (SIGCHI) which publishes a quarterly newsletter and holds regularly scheduled conferences. The American Society for Information Science (ASIS) has a Special Interest Group on User On-line Interaction (SIGUOI) which publishes a quarterly newsletter and participates by organizing sessions at the annual ASIS convention. The International Federation for Information Processing has a working group WG 6.3 on human computer interaction which publishes a quarterly newsletter called Interact. The Human

Factors Society has a Computer Systems Group with a quarterly newsletter, as well.

Conferences, such as the ones held by the ACM, ASIS, National Computer Conference Board of AFIPS, Human Factors Society, and IFIP often have relevant papers presented and published in the proceedings. The list of guidelines documents, books, and articles may be seen as a starting point to the large and growing literature in this area.

8. POTENTIAL RESEARCH PROJECTS

There are so many fruitful directions for research that any list can only be a provocative starting point. These topics indicate my thoughts about where effort could and should be applied:

1) Response time, display rates, and operator productivity - many computer professionals believe in the simple principle that faster is always better. There is evidence from several IBM studies and other sources that programmers are more productive when system response time is kept within the one second range or even faster. On the other hand isolated studies have shown that in some business decision making tasks, computer assisted instruction, complex order entry, and introductory sessions with novices rapid performance leads to poorer learning, less effective decisions, higher error rates, and occasionally decreased satisfaction. A thorough study of multiple tasks with a variety of user communities would shed light on which situations would be improved with shorter response times or faster display rates. Understanding psychological issues of short-term memory load, decision making strategies, and information overload would help in preparing design guidelines for system implementers.

2) Menu selection - menu selection is offered on many systems for novice users, but there is little data to support design guidelines. The content, number, placement, and phrasing of menu choices could be studied with attention to titling of menu frames, effectiveness of instructions, availability of type-ahead strategies or menu shortcuts, backtracking, and graphic design to show hierarchical organization. Much progress could be made in this area with modest experimental efforts. There is also an

opportunity to investigate software architectures for menu management systems, which dramatically reduce the amount of code while permitting end users to develop and maintain their own menus.

3) Command languages - this traditional style of interaction is another excellent candidate for research to understand the importance of consistency in syntactic format, congruent pairings of commands, hierarchical structure, choice of familiar command names and parameters, suitable abbreviated forms, automatic command completion, and interference from multiple routes to accomplish the same task. The impact of response time and novel hardware display and entry devices on the command set is another worthy topic.

4) Graceful evolution - although novices may begin with menu selection, they may wish to evolve to faster or more powerful facilities. Methods for smoothing the transition from novice to intermittent knowledgeable to frequent expert could be studied. The differing needs of novice and experts in prompting, error messages, on-line assistance, display complexity, locus of control, pacing, and informative feedback need investigation.

5) Anxiety and fear of computer usage - although computers are widely used, they still serve only a fraction of the population. Many people avoid using computerized devices, such as bank terminals or word processors, because they are anxious or even fearful of breaking the computer, making an embarrassing mistake or being incapable of succeeding. Interviews with non-users of computers would help determine the sources of this anxiety and lead to design guidelines to alleviate the fear. Tests could be run to determine the effectiveness of re-design of systems and of improved training procedures.

6) Specification and implementation of interaction - most interactive systems are constructed with traditional procedural languages, but novel techniques could reduce implementation times by an order of magnitude. Specification languages and dialog management systems have been proposed and some commercial packages are available. Advanced research on tools to aid

interactive systems designers and implementers might have substantial payoff in reducing costs and improving quality.

7) Direct manipulation - graphical interfaces in which the user operates on a representation of the objects of interest are extremely attractive in computer assisted design and manufacturing, video games, database query, electronic spreadsheets, display editors, etc. Empirical studies would refine our understanding of what is an appropriate analogical representation and the role of rapid, incremental, reversible operations.

8) On-line assistance - although many systems offer some help or tutorial information on-line, there is limited understanding of what constitutes effective design for novices, intermittent knowledgeable users, and experts. The role of these aids and on-line user consultants could be studied to assess their impact on user success and satisfaction. The utility of a separate display or window for assistance or tutorials should be contrasted with the common approach of entering a separate subsystem which displaces the current display of work.

9) Hardware devices - the plethora of keyboards, displays, and pointing devices presents opportunities and challenges to system designers. The heated discussions about the relative merits of lightpens, touchscreens, voice input, function keys, or high resolution displays could be resolved through extensive experimentation with multiple tasks and user communities. Underlying issues include speed, accuracy, fatigue, error correction, and subjective satisfaction.

10) Programming style - comprehensibility of programs is effected by cosmetic issues such as commenting, indentation, choice of mnemonic names, and use of blank space. Structural issues such as number of arguments in a module, global vs. local variables, nested conditionals vs. expanded Boolean expressions, use of pointers, structured control structures, and data abstraction also influence comprehensibility. Although studies have been performed for some of these issues much work remains.

11) Programmer workstations - programmer productivity might be substantially raised by an improved workstation. Rapid response

time, high resolution graphics, high-speed printers, adequate on-line library facilities, advanced editors, program analysis tools, and advanced debugging software need to be implemented, tested, and refined for the professional programmer environment.

12) Program documentation - many organizations have standards for internal and external documentation, but realistic evaluations of effectiveness are rare. Comprehensive trials of documentation style for control flow, data structures, module interfaces, concurrency, and real time constraints would produce guidelines to practitioners and insights to the cognitive processes of program comprehension. A major beneficiary of these results would be program maintenance organizations.

9. GOALS

Clear goals are useful, not only for system development, but also for educational and professional enterprises. In the past decade, I have been working on human factors issues with three primary goals - influencing academic and industrial researchers, providing tools, techniques and knowledge for commercial systems implementers, and raising the consciousness of the general public.

Influencing academic and industrial researchers

Early research in human-computer interaction was done largely by introspection and intuition, but this approach suffered from lack of validity, generality, and precision. By applying the techniques of controlled psychologically oriented experimentation, I believe we can obtain a deeper understanding of the fundamental principles of human interaction with computers.

The reductionist scientific method has this basic outline:

- lucid statement of a testable hypothesis
- manipulation of a small number of independent variables
- measurement of specific dependent variables
- careful selection and assignment of subjects
- control for biasing
- application of statistical tests

Materials and methods must be tested by pilot experiments and results must be validated by replication in variant situations.

Of course, the highly developed and structured method of controlled experimentation has its weaknesses. It may be difficult or expensive to find adequate subjects and laboratory-like conditions may distort the situation so much that the conclusions have no application. When results for large groups of subjects are arrived at by statistical aggregation, extremely good or poor performance by individuals may be overlooked. Furthermore, anecdotal evidence or individual insights may be given too little emphasis, because of the authoritative impact of statistics.

In spite of these concerns, controlled experimentation provides a productive basis which can be modified to suit the situation. Anecdotal experiences and subjective reactions should be recorded, thinking aloud or protocol approaches should be employed, field or case studies with extensive performance data collection should be carried out, and the individual insights of researchers, designers, and experimental participants should be captured.

Within computer science, there is a growing awareness of the need for greater attention to human factors issues. Researchers who propose new programming language or data structure constructs are more aware of the need to match human cognitive skills. Developers of advanced graphics systems, robots, computer assisted design systems, or artificial intelligence applications increasingly recognize that the success of their proposals depends on the construction of a suitable human interface. Researchers in these and other areas are making efforts to understand and measure human performance.

In psychology, there is a grand opportunity to apply the knowledge and techniques of traditional psychology, and recent subfields such as cognitive psychology, to the study of human-computer interaction. Psychologists are investigating human problem solving with computers to gain an understanding of cognitive processes and memory structures. The benefit to psychology is great, but psychologists also have the golden opportunity to dramatically influence an important and widely used technology.

Researchers in information science, business and management, education, sociology and in other disciplines are benefitting and contributing by their study of human-computer interaction.

Tools and techniques for systems developers

Commercial systems managers, designers, and implementers are emerging from benign neglect of human engineering. There is a great thirst for knowledge, for software tools, for design guidelines, and for testing techniques. Dialog management software packages are appearing to provide support for rapid prototype and system development, while aiding design consistency and simplifying evolutionary refinement or maintenance. Guidelines documents are being written for general audiences and for specific applications. Many projects are taking the productive route of writing their own guidelines specifically tied to the problems of their application environment. These guidelines are constructed from experimental results, experience with actual systems, and some knowledgeable guesswork.

Pilot and acceptance testing is appropriate during system development. Once the initial system is available refinements can be made on the basis of on-line or printed surveys, individual or group interviews, or from more controlled empirical tests of novel strategies.

Feedback from users during the development process and for evolutionary refinement can provide useful insights and guidance. An on-line electronic mail facility allows users to send comments directly to the designers. On-line user consultants can provide prompt assistance and much information about the activity and problems of the user community.

Raising the consciousness of the general public

The media is so filled with stories about computers, that public consciousness raising may seem unnecessary. But in fact, many people are anxious and fearful about using computers. When they do finally use a bank terminal or word processor they are fearful of making mistakes, anxious about breaking the computer, worried about feeling incompetent, or threatened by the computer "being smarter than I am". These fears are justified, in part, by the poor designs which have complex syntactic forms, hostile, condemning, and unhelpful messages, and the misleading anthropomorphic style of some systems.

Part of my effort has been devoted to educating the general public to put their internal fears into action. Instead of feeling guilty or inadequate when they get a message like "SYNTAX ERROR", they should express their anger at the system designer who was so inconsiderate and thoughtless. As examples of successful and satisfying systems become more visible, the crude designs will appear increasingly archaic and become commercial failures. As designers improve interactive systems, some of these fears will recede and the positive experience of competence, mastery, and satisfaction will flow in. Then the image of computer scientists and data processing professionals will change in the public's view. The machine oriented and technical image will give way to one of personal warmth, sensitivity and concern for the user.

10. PRACTITIONER'S SUMMARY

If you are working on a project where there is substantial concern for short learning times, rapid task performance, low error rates, user satisfaction, and ease of retention, then you should set measurable goals with pilot studies and acceptance tests. There is a rapidly growing literature and sets of design guidelines which may be of assistance. Each new application has its special cases and you can keep on course by involving users during the design, through development, and for evolutionary refinement. Error frequency data and command utilization statistics are useful in tuning the system. Subjective satisfaction can be measured through on-line or printed surveys, while unstructured feedback can be obtained from electronic mail and user consultants.

11. RESEARCHER'S AGENDA

The opportunities for researchers are unlimited. There are so many interesting, important, and doable projects, that it may be hard to choose a direction. Begin by understanding the practical background of the problem, consider the fundamental psychological principles of human behavior, and propose a lucid, testable hypothesis. Then consider the appropriate research methodology, collect the data, and analyze the results. Finally, return to the practical application area with specific recommendations and refine your model of human performance.

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--An early and influential document which is the basis for several of the other guidelines documents.

Smith, Sid L., User-System Interface Design for Computer-Based Information Systems, Report ESD-TR-82-132. The MITRE Corporation, Bedford, MA 01730, Electronic Systems Division, (April 1982), 181 pages.

--This thorough document, which is continuously being revised, begins with a good discussion of human factors issues in design and then covers data entry, data display, and sequence control. Guidelines are offered with comments, examples, exceptions, and references. Sid Smith is seeking comments for refinement and expansion, telephone 617-271-7768.

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