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HUMAN FACTORS IN COMPUTER SYSTEMS:
REVIEW OF THE LITERATURE AND
DEVELOPMENT OF DESIGN AIDS
(FINAL REPORT)

Technical Report SAI-79-113-DEN

Science Applications, Inc.
7935 E. Prentice Avenue
Englewood, CO 80111

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40 Denver Technological Center West, 7935 East Prentice Avenue, Englewood, Colorado 80111, 303/773-6900

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Two technical reports were issued under this contract. The first is a critically annotated and heavily indexed bibliography of 564 reports selected from the surveyed literature. The second is a critical overview of the state of the art, with recommendations for a design guide. The basic conclusion of this study is that a human factors design guide for interactive systems -- which discusses issues, alternatives, and methods in the context of the design process -- is both feasible and needed. The current state of the art was not found adequate to support the development of a quantitative reference handbook in this area.

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TO: Chief of Naval Research, Arlington, Virginia 22217
Attention: Engineering Psychology Programs, Code 455,
Dr. John J. O'Hare

FROM: H. Rudy Ramsey, Science Applications, Inc.
Englewood, Colorado 80111

SUBJECT: Final report of work completed under the support of Contract
N00014-76-C-0866, between Science Applications, Inc., and the
Engineering Psychology Programs, Office of Naval Research.

This constitutes a final report of work completed under the support of Contract N00014-76-C-0866, Work Unit Number NR196-146, between Science Applications, Inc. and the Engineering Psychology Programs, Office of Naval Research. The contract was initiated 1 June 1976, and was terminated 31 July 1979.

The mission of this contract was to survey the literature in the area of human factors in computer systems. Immediate goals were: (1) the development of a bibliography describing and critically evaluating the important individual papers in the field, and (2) the development of an integrative and critical evaluation of the state of the art in the area. This state-of-the-art survey was intended primarily to assess whether our current knowledge in this area is adequate to develop a human factors guide to computer system design.

The remainder of this report provides an overview of the research performed under this contract, outlines our conclusions, and lists the publications resulting from the study.

LITERATURE SURVEY

Human factors in computer systems is by nature a highly interdisciplinary field. As a result, the relevant literature is widely scattered. Those who would perform effective application work in this area must be aware of a broad range of literature, including: (a) the general literature on human factors, as well as that concerned specifically with computer systems, displays, data entry, and specific application areas; (b) a significant segment of the basic psychological literature, including especially the areas of perception, information processing, and cognitive psychology; and (c) a significant segment of the computer science literature, including especially the areas of batch and interactive languages, display and input devices and techniques, and specific application areas.

Prior to this research project, this broad literature had not been satisfactorily surveyed in recent times. With an increasing breadth and volume of literature in the field, it has become increasingly difficult for researchers, new human factors personnel, and system designers to acquire and maintain familiarity. There was a clear need for greater synthesis of this information into a form useable by such personnel. The form which has the greatest potential payoff in terms of research utilization is a human factors guide to computer system design.

As a first step in integrating this information, a very broad survey of the literature dealing with human factors in computer systems was performed. Included in the survey were books, journal articles, proceedings papers and institutional publications from the literatures of psychology, human factors, and computer science. From the resulting list, 564 references were selected for inclusion in a bibliography.

The references selected deal primarily with the human factors aspects of interactive computer systems, including hardware, software and procedures. The selection of references emphasizes experimental studies, but the bibliography also includes relevant descriptions of

dialogue techniques, user requirements analysis methods, guidelines, and a variety of other relevant topics.

For each reference, the bibliography presents a citation with sufficient information to allow the reader to obtain a copy. For each reference, both a descriptive abstract and a critical annotation are presented. An extensive subject index, as well as an author index and browsing aids, allow the location of documents of interest to a particular user.

The bibliography is reference 1 in the list of technical reports at the back of this final report.

STATE-OF-THE-ART REVIEW

Although the bibliography was intended to be useful in itself, its more important function in this project was as the initial step toward a critical, integrative review of the state of the art in the area. Such a review report was prepared. This proved to be a difficult task, primarily because it attempted to integrate information at a fairly detailed level across a very broad field.

The review report attempts to describe the current state of the art in human factors research and in actual practice in the design of interactive systems. The report covers such topics as:

- User and Task Properties
- Requirements Analysis Techniques
- Problem-solving Aids
- Interactive Dialogue
- Output Devices and Techniques
- Input Devices and Techniques

Wherever possible, the report presents this descriptive information in the form of tables, with critical comments and references to the most relevant source documents.

The main emphasis throughout this report was on the information needs of the system designer and on the feasibility and nature of human factors guidelines which might satisfy those needs. The principal conclusion was that insufficient data exist for the development of a "quantitative reference handbook" in this area, but that a "human factors design guide" -- which discusses issues, alternatives, and methods in the context of the design process -- is both feasible and needed.

This conclusion results from two principal factors. First, the research literature, while quite large, is fragmented and inadequate to support anything approaching a quantitative reference handbook of

the type produced in classical human engineering areas. Second, and perhaps even more important, it is not clear that the problem-solving behavior of the interactive system designer is consistent with such a reference work.

The design decisions for which a reference handbook is used must be explicitly identified by the designer. In "classical" system design situations, this may be a reasonable expectation. When a design engineer encounters issues such as level of illumination, size of control knobs, or type and position of a numerical display, the design decision involved tends to be: (1) quantitative, (2) explicit, and (3) clearly associated with the "operator interface", and therefore closely identifiable with human factors. Even here, there is evidence which suggests that designers may proceed without consulting readily available human factors handbooks.

In the design of interactive computer systems, virtually every decision which affects the functional behavior of the system has direct human factors overtones. This claim can be made in the cases of automobiles, aircraft, and radios, too, but only in a much weaker sense. In a system whose basic function is communication with a user, and whose basic purpose often is to assist the user with tasks which are cognitive or informational in nature, human factors issues pervade the entire design process.

Furthermore, the important design decisions may not be explicitly recognized. It appears that the primary problem-solving method employed in design tasks is an "analytic/synthetic" approach. This approach involves an analysis of the design problem, in which the components of the problem are identified, followed by the synthesis of a solution. It does not involve an explicit search for alternative solutions; instead, a solution is "synthesized" based on pattern recognition and the use of components from past solutions to other problems.

If, in interactive systems, the design decisions which involve human factors issues are pervasive, implicit, and often qualitative, a

reference handbook is unlikely to be effective. However, there is another mechanism for providing human factors guidance to the system designer, which appears to be more compatible with the design process and the designer's information needs. It also appears to be more compatible with the current state of our knowledge. This approach is the design guide.

As the term is used here, a "design guide" is a document whose structure parallels the major steps of the design process itself. Although such a guide should be indexed sufficiently that it can be consulted with a specific question after that question has been identified, that is not the design guide's primary mode of use. It is intended to be consulted during the analytic process, before design decisions are made. Such a guide must identify issues, suggest alternatives, and present (where they exist) hard human-factors data at the point in the design process at which this information is most relevant.

Clearly, this is more of a "how-to-do-it" document than has typically been undertaken by human factors personnel. Such an approach appears justified, however, by several factors: (1) the pervasiveness of human factors issues throughout the interactive system design process; (2) the likelihood that a reference handbook would not be consulted and used effectively; (3) greater compatibility with the problem-solving behavior and information needs of the system designer; (4) inadequacy of the existing human factors data base to support development of a quantitative reference handbook; (5) comprehensiveness, in the sense that this format allows discussion and some guidance even in areas in which specific experimental data are lacking; and (6) the fact that this general format is capable of encompassing not only human factors data, but also applied human factors methods.

The review report attempts to indicate for each topic covered, the availability and quality of existing guidelines which could be integrated into such a document, and/or the nature and difficulty of the effort required to formulate such guidelines in areas in which existing

guidelines are inadequate. The review report is reference 2 in the list of Technical Reports, which follows.

TECHNICAL REPORTS

1. Ramsey, H. R., Atwood, M. E., & Kirshbaum, P. J. A critically annotated bibliography of the literature on human factors in computer systems (Technical Report SAI-78-070-DEN). Englewood, Colorado: Science Applications, Inc., May 1978. (NTIS No. AD A058081; JSAS No. MS-1822)
2. Ramsey, H. R., & Atwood, M. E. Human factors in computer systems: A review of the literature (Technical Report SAI-79-111-DEN). Englewood, Colorado: Science Applications, Inc., July 1979.

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