Gouvernement du Canada
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Le Centre canadien de recherche sur l'informatisation du travail
Canadian Workplace Automation Research Centre

Cognitive Ergonomics of Information Processing Systems: Status and Research

EXECUTIVE SUMMARY

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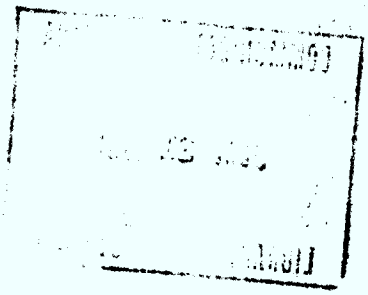
July 1987

This document was produced during the course of a research project at Canadian Workplace Automation Research Centre, Organizational Research Directorate., Communications Canada. Opinions expressed within are those of the authors.
* The complete report is available in French.
* La version intégrale du rapport et le sommaire sont disponibles en français

DOC - CWARC - ORD 85/6-019



SUMMARY

Cognitive ergonomics of information processing systems is a new field. This report outlines the current status of research, and describes the principal ergonomic problems posed by new information processing technology, as well as the methods used to solve them and the results obtained. The authors also suggest new research directions likely to further knowledge in this field. The report contains six chapters. The first two describe cognitive ergonomics in relation to other fields of scientific research, and give a general outline of the problems involved. Chapters 3, 4 and 5 in turn describe the three major aspects of person-computer interaction: the information processing system, the human user, and the task. The sixth chapter contains four recommendations for further research.

Chapter 1: Development of cognitive ergonomics

The first section of this chapter relates cognitive ergonomics to traditional ergonomics, and indicates how the advent of information processing technology has altered our concepts of tools and machines. In the past, traditional tools and machines were designed to operate on physical objects; the computer, by contrast, is essentially designed to manipulate information. This new tool has led us to redefine ergonomics as a discipline. The traditional goal of adapting the work to the person and the machine to the operator remains unaltered, but adaptation can no longer be limited to the user's perceptual and motor skills alone; it must also include his cognitive functions. Knowledge derived from disciplines such as cognitive psychology and artificial intelligence therefore become not only relevant, but also necessary in resolving ergonomic problems posed by the person-computer relationship. The following section of the chapter describes the creation of the first research centres in the field, as well as the founding of learned societies and the appearance of specialized journals. This section also contains a list of the major research groups working on person-computer interaction. In light of the large number of disciplines interested in ergonomics research, it is hardly surprising to find several different methodological approaches, which the third and last section of the chapter divides into four broad schools of thought. The guideline school, as its name indicates, aims at establishing basic principles to guide engineers in designing systems better adapted to users. The experimental school is characterized by its use of classic scientific methodology. This approach can be directed toward a variety of goals, such as validating fundamental theories on person-computer interaction, or carrying out specific tests on systems either already in existence or currently being developed.

The calculational school focusses on developing models that will predict, in numerical terms, the consequences on user performance of variations in system design. This reduces the need for empirical testing, which often costs a great deal of time and money. Lastly, the intelligent interface school is working toward building systems that are inherently capable of adapting themselves to the user.

Chapter 2: The optimal user-computer system

Although most researchers in cognitive ergonomics are trying to facilitate person-computer interaction, few can agree on how to do so. Chapter 2 attempts to define the general concept of a user-computer interface. The first section defines the interface in several ways, and shows that an overly restrictive definition, limited to the points of physical contact between user and machine, allows little scope for improving the person-computer relationship. The second section describes a general model of what we may call a user-computer system. The model has three major components: the information processing system, the user, and the task which motivates interaction. The information processing system itself has several components: the interface software, the interface hardware, and the internal hardware of the machine. For users, we must distinguish between basic cognitive abilities common to all, and differences which may exist between individuals or groups. Ideally, we should also take into account the variations that may occur in a single user at different stages of familiarization with the system, or even during a single interaction session. We should also note that the computer can perform increasingly varied tasks, which differ not only in their nature but also in the complexity of the modes of interaction. These modes are called operating languages.

The third section of the chapter lists ten criteria proposed to evaluate man-computer interaction. Some of the criteria are related to user performance: speed of executing a task, error rate, and ease with which errors can be corrected. Others are related to learning: facility with which system-related knowledge can be acquired, retained, and applied to other systems. The remaining criteria are: power and flexibility of the system, acceptability, and the degree to which it is used. Unfortunately, it is almost always impossible to satisfy all ten criteria, and often difficult to choose which to discard at any given time.

Chapter 3: The system

This chapter examines the information processing system itself. Clearly, cognitive ergonomics is mainly concerned with the interface software of any information processing system. Limitations on interface software are ultimately imposed both by the interface hardware and the computational power of the machine. Thus, the first section of the chapter briefly describes some aspects of internal computer structure. The second describes interface hardware, including principal input modes, such as

keyboards and various cursor-positioning systems, and principal output modes, such as printers and screens. Some of the research on multimodal interfaces is also cited. These sections reveal the enormous technological resources available to software creators. As a result, it seems that limitations on existing interface software stem largely from gaps in our theoretical knowledge of information processing in general, and within the human brain in particular. The third section describes the cognitive interface and reviews studies illustrating the problems that users have with learning and using the types of artificial syntax and vocabulary required to interact with the computer. These problems would be partially solved if users could interact with the computer verbally and use natural language. As yet, however, there is no general procedure for recognizing speech or understanding language automatically. In addition, this section briefly covers a relatively new type of interface: concepts are represented by images, commonly called icons, which are then manipulated directly. Although such interfaces do seem easier to use, we still know little about the way in which space and images are represented in the user's mind.

Chapter 4: The user

The first section begins with a model of a typical user. Although based on 20 years of research in cognitive psychology, the model encompasses only basic cognitive skills, which all users should therefore have. The second section discusses the differences between users that have been identified and studied. One line of research derives from classic differential psychology, and examines differences in aptitudes, skills and styles among various users of information processing systems. A second line derives from ergonomics and classifies users by more pragmatic criteria, such as the nature of their work, motivation and level of expertise. The latter two criteria illustrate one of the problems inherent in such classifications: a single user can change category as his level of expertise, or even daily motivation, changes. The only way to take these variations into account is by creating more flexible interfaces which can adapt to the requirements of the user. The last section describes several different approaches to the problems of interface in artificial intelligence.

Chapter 5: The task

After a look at tasks in general, this chapter focusses on the three major tasks in office automation: word processing, creation and retrieval of data in data banks, and electronic mail. The first section discusses text editing, which undoubtedly has received the most attention in cognitive ergonomics. Studies presenting widely differing viewpoints are also discussed. The following section examines data banks, and reveals that whereas most problems encountered in word processing are rooted in the syntax of a system, data banks pose mainly semantic problems. Various ways of organizing information in data banks are described, as well as various modes of access. The last section deals with electronic mail, and considers

at some length the problem of electronic junk mail: how to discriminate between relevant and irrelevant messages. This may seem of little importance, but in a world where communication is electronic, lack of selectivity in distributing messages can cost a great deal of time and money. However, if selectivity were too strict, important messages might be prevented from reaching their proper destinations. The section proposes several solutions.

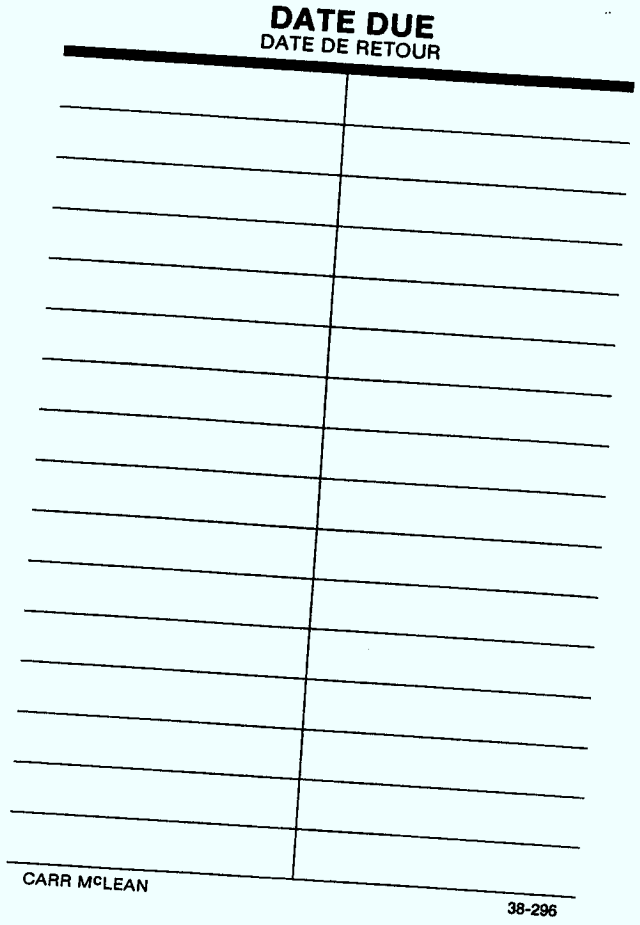
Chapter 6: Lines of research

The last chapter is deliberately more speculative than the first five. Here the authors describe the lines of research they feel will contribute most toward the development of optimal interaction. Their first recommendation is for research on direct manipulation interfaces, since this is a new field which needs to be developed and more widely applied. However, very little is known about the cognitive advantages of such interfaces or the way they are represented in the user's mind.

Their second recommendation is for the study of mental models developed by users. We must gain a better understanding of how users perceive the system with which they interact. Several studies reveal that users generally have inadequate mental models, which result in non-optimal use of the system and paralyze users when they make an error.

The third recommendation concerns the development of intelligent interfaces, which derive from research in artificial intelligence. It is important for systems to have a better inherent "understanding" of the user and task. The authors therefore recommend that artificial intelligence research be pursued and applied to interface development even if there are no immediate benefits.

The fourth and last recommendation is for the study of what may be called the "organizational interface," the way in which people organize their work individually and collectively. There are various indications that the quality of interaction depends not only on the system, user and task, but also on the organizational context in which interaction takes place; for example, secretaries are often subject to constraints which limit mastery of their machines, such as management being unwilling to allow the time necessary for adequate training. It is also essential to analyse how the use of information processing technology fits into the general context of the user's tasks, so that its impact on the overall productivity of both user and organization can be assessed.



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