ABSTRACTS

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WORKING WITH COMPUTERS: THEORY VERSUS OUTCOME

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MODELS AND THEORIES IN COGNITIVE ERGONOMICS

Formalisable Models Of User Knowledge In Human-Computer Interaction

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The virtues and vices of formalisms are well known. On the one hand, they are precise, and by their precision they reveal slipshod thinking or unwarranted assumptions; on the other hand, when the material to be formalised fails to conform to the expected structure, formal systems encourage ingenuity in squeezing difficult material into shape rather than rethinking the system and developing a better approach. At its worst, a formal system is unable to generate testable predictions and its adherents split the finer points of pedantry into smaller and still smaller hairs. But at its best, it enables meaningful predictions to be made in the real world.

In this chapter we are concerned with formalisms for expressing tile knowledge required to use applications programs, such as text editors, spreadsheets, and interactive graphics programs. We are particularly concerned with representing expert knowledge of how to use the applications program, and with using that representation to obtain predictions of difficulties in learning and performance. Since it is knowledge about the program, rather its application domain, that concerns us here, the tasks we shall study are tasks of program usage, such as "how to edit a formula in this spreadsheet". They will not be tasks in which knowledge of the application domain is paramount, such as how to perform revenue forecasting. In the terms of Moran (1983) we shall be studying "internal" tasks rather than "external" ones.

Knowledge-Based Task Analysis For Human-Computer Systems

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The analysis of tasks is a fundamental and important process in many areas of applied behavioural science. Task analysis offers methods for exploring relationships between the properties of systems and user performance.

Traditionally (e.g. see Miller, 1962), the analyst takes descriptions of the cues that should be perceived and the actions that should be performed, and maps these onto behavioural units; but working with computers presents novel problems. It is the user's conceptual skills, not the perceptual motor skills of a previous generation of technology, that must now be automated.

Successful task execution now depends critically on the user's knowledge of the system, its properties, capabilities, and requirements. Units of behaviour can no longer usefully be viewed in isolation.

We shall review recent progress towards incorporating knowledge requirements into task analysis, comparing eleven forms of task analysis. All have been developed with the aim of describing knowledge intensive tasks in HCI; but naturally enough, different techniques address different aspects in differing degrees of detail, and some techniques have been more fully developed than others. The major characteristics we shall stress are the following.

On Mental Models And The User Interface

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This chapter addresses a fundamental problem in theoretical HCI. It has now become widely accepted that when a person uses a device, part of that person's knowledge about the device includes a "mental model", as described below, but the range and variety of the mental models postulated in the literature has been diverse and untrammelled. This exuberant approach to theorising seems false; theorists have acted as though there were no bounds whatever on the possible mental models, and that the mental model formed in one situation had nothing at all in common with the model formed in another situation. Not just the topic of the mental model, but also the form of the mental model has been treated in a thoroughly ad hoc, arbitrary manner.

It is our aim to propose a unifying description. We shall argue for the existence of a "language in the head" in which all conceptual structures can be represented. The most effective means to argue this position, and to demonstrate its relevance to HCI, is to show how such a "language in the head" can be formally represented, and to use the formalism to rephrase one of the existing accounts of a user's knowledge about a device. Two formalisms have been worked out which are candidate accounts of the "language in the head", one by Klix (1984) and one by Jackendoff (1983).

In each case, the claim is that all knowledge - and therefore, a fortiori, "mental model" knowledge - is represented in a form that can be described using the formalism. However, there has been no previous attempt to rephrase any of the existing mental models postulated in the literature in terms of either of these formalisms.

We shall adopt Jackendoffs account and will use it to present a reformulation of Payne & Green's (1986) "Task-Action Grammar", TAG. Task Action Grammar is presented in detail elsewhere in this volume, by Green et al., and it is an attempt to give a formal description of the knowledge held by the user of a device. Our reformulation, Extended TAG or ETAG, not only places TAG on a more stringent theoretical basis, but also allows the theory to be extended to cover more of the underlying semantics than was previously possible. An important result from the development of ETAG is that we have been able to describe some of the consequences of design decisions that were not treated by the original version of TAG - especially decisions about how much information to reveal to the user. To demonstrate this, we shall investigate a particular example in some depth.

The structure of this chapter therefore is as follows. First we shall briefly describe the essentials of the particular program that is to be used as an example. Then we shall introduce the notion of "mental model" and show why it is important to seek formal descriptions of such models. Next we shall put mental model theory into the context of general model theory and show that to understand the architecture of mental models, it is necessary to obtain an account of the tasks that the user intends to accomplish. We shall then introduce Jackendoff's theory of conceptual structure and use it to develop ETAG.

EMPIRICAL EVIDENCE IN COGNITIVE ERGONOMICS

Conceptual Models For Designing Information Systems

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Although the roles played by both programmers and end-users have attracted a great deal of attention in Human Factors research, those of the Systems Analyst and Designer still await investigation. The following paper addresses this issue when considering basic conceptual models of Information Systems Design.

The Introduction describes the design of information systems in general while the major part of the paper deals with the different conceptual models existing in Information Systems Design. A number of fundamental methods are presented and examples from a Higher Education Planning System and some common application packages are given.

The Other Interface: Specifying And Visualising Computer Systems

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Human-computer interaction is often taken to refer exclusively to interaction between end users and computer systems, and recently a great deal of well-placed effort has been spent in studying the design of user interfaces.

There is, however, another "interface" of arguably greater importance to the acceptability of any computer system. This is the "procurement interface" between client and developer. Both parties must understand and agree upon a description of the envisaged system. The client must know what he is going to get (and pay good money for) and the developer must know what he is being paid to do. If the procurement interface fails and undetected misunderstandings arise some of the classic and well-documented symptoms of the "software crisis" result.

Software developers seldom have knowledge of and expertise in the application domain to match that of the client. Their skills lie elsewhere. But a detailed knowledge of the application domain may be necessary for a developer to understand the client's requirements. Consequent communication failures can range from simple misunderstandings over terminology - because the developer interprets in its everyday sense a word that has a more precise domain-specific meaning - to a failure to appreciate fully the implications of a requirement because the developer cannot conceptualise application knowledge as richly as the client.

Another problem associated with the procurement interface is the complexity of the information that passes across it. Even if tile developer and client can communicate effectively and reliably, the size and inter-relatedness of the total set of requirements for an industrial computer system is such that careful attention must be paid to its organisation and representation. Everyone knows how complicated and difficult to understand even an existing, working system can be. It is far more difficult to come to a thorough understanding of a non-existent, planned system from a complex description.

The cognitive ergonomic implications of these observations about the procurement interface, unlike those pertaining to the design of user interfaces, have received only unsystematic and anecdotal attention. It is the purpose of this chapter to explain the various approaches to specifying systems from such a perspective. It is hoped that this chapter will help readers with a background in psychology to be able to make more sense of the software engineering literature on specification. Likewise, software engineers should be encouraged to see the issues discussed in an unfamiliar but profitable light.

Intervening Into System Development Area Projects: Tools For Mapping Situations

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In this chapter we propose some new tools for mapping system development projects. Maps - as we propose them - contain descriptions and interpretations of project situations: they are helpful in collecting and organising relevant, often neglected knowledge and experience. Maps are cognitive constructs containing pictures that actors make of the situation in which they are involved. They are typically made within the situation or transposed from similar situations and are used by the actors themselves as tools for exploring, for learning, for increasing awareness, for inventing solutions to problems, and for undertaking action.

Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost ill information? "Choruses from the Rock" T.S. Eliot

Towards Effective Computer Aids To Planning In Computer Programming Theoretical Concern And Empirical Evidence Drawn From Assessment Of A Prototype

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For about fifteen years, a lot of research work has been published on the psychology of programming. In most cases diverse kinds of static characteristics of the programming environment have been emphasised. for example, language features or program lay-outs. In addition, attention has very often turned to novices and very seldom to professional programmers. The growth of software factories requires a shift of attention towards dynamic aids to expert programmers' activity. This paper is devoted to planning, which is a crucial feature of this expert activity. It briefly describes a framework for the study of planning, derived from psychology and artificial intelligence, and reports evidence drawn from an empirical assessment of computer aids to programming. It illustrates the relevance of a theoretical approach to designing experimental situations, the enrichment of the framework gained from empirical evidence, and the benefits of this procedure in designing effective computer aids. The results stress: (a) the crucial role of problem type in planning guidance needs, (b) the limitations of traditional programming languages when subject wants to express schematic representations at the onset of design, (c) the disturbances in working memory when parallel presentation of information is not available, and (d) the importance of familiarisation effects with new tools (even with experts) before getting relevant evidence from experimental assessment.

COMPUTERS AND THE INDIVIDUAL

Computers And Education Adaptation To Individual Differences

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In this contribution a review will be presented of a long-term project on computers in education, for the greater part concentrated on the primary school. This research went on at the Free University of Amsterdam for 15 years. During that time a lot of changes took place: theoretical notions developed, hardware possibilities were realised as new generations of computer systems became available, and application in the classroom was facilitated both by these facts and by the changing appreciation in society, of which teachers are part.

In this large scale project (comprising 95 man years of the research team, not to mention teachers and pupils) it was unthinkable that goals did not change. New hypotheses replaced former ones, and research in other centres influenced the directions of thought. But the central topics of research remained the same: -- The role of computers in education, and their effect on the traditional learning and thinking in the school. In this respect concentration was on individualisation, that is adaptation of the teaching strategy to individual differences between students. -- The new teaching strategies that may be derived from the introduction of computers in the classroom and the extent to which the existing tool-box of the teacher is enriched and provided with new elements in the learning environment. -- New components that may be inserted in the curriculum, as a result of the availability of computers (cognitive skills that are not part of the traditional subject matter in primary schools).

These questions were investigated from the point of view of cognitive psychology. Adaptation to individual differences in cognitive functions was the main interest in this project, guiding the experiments and observations over the years.

Section 1 will present a historic overview of the project. In the second section a dimension of changeability will be introduced, that will be a guideline for developing goals for adaptation to individual differences. Section 3 contains a systematic overview of empirical data on the relation between the changeability of variables, and the possibilities to adapt in teaching with the help of computers. Observations from real life classroom situations are illustrated in section 4, after which the contribution ends with some remarks on the role of the teacher and the impact of computer applications for the curriculum.

The Impact Of Individual Differences In Programmers

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Managers readily admit the sizeable individual differences they have observed ill skill and performance among programmers. Although these differences are part of the popular lore in software engineering, the seriousness of their impact is usually overlooked in identifying the points of greatest leverage for improving programming productivity and quality. This paper organises and reviews data bearing on individual differences among professional programmers collected by the author and others in laboratory experiments and on actual projects. The paper argues that individual differences are still the largest source of leverage available for improving productivity and quality. Unfortunately, they receive miniscule research attention in relation to their impact on software development performance and costs.

Finally, the productivity improvements promised by many advances in software technology will be masked by the continued impact of individual differences on productivity data.

The Individual And Organisational Impact Of New Technology

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The aim of this chapter is to argue that, to a large extent, the nature of the impacts of new technology at both the individual and organisational levels, depend upon the implementation strategies of those with the responsibility for designing the system. The chapter begins with an overview of the major themes in psychological research relating to the implementation of computer-based new technologies in work settings. For the sake of simplicity, I will concentrate mainly on the area of computer aided manufacturing (CAM). Also, I will use the term "new technology" to refer particularly to the various information technologies involved in advanced manufacturing methods. Another distinction which is crucial to some parts of this argument is that between mechanisation and automation. Basically, automation is here conceived of as a process rather than an end state. Mechanisation is a transition phase through which most examples of automation pass. The essential difference between the two resides in the form of the tasks which are carried out by the two types of system. Mechanisation is seen essentially as a process whereby certain of the physical tasks previously carried out by individuals come to be performed by machines. Automation, on the other hand, also involves the performance by machines of certain of the judgemental and control procedures necessary in production.

One of the problems with the body of literature relating to the job content effects of new technology is the scarcity of relevant empirical studies. No doubt this is in part attributable to the speed of technological development and the rapidity of technological change, but also to the methodological difficulties posed by the diverse nature of the technologies in use in different applications. In addition, another salient feature of this literature is that a relatively small number of themes and concepts have tended to dominate what research has been done in the area. These include what is often called the "job design/redesign tradition", the "deskilling debate", which is usually held to be the major contribution of labour process theorists to the area, and the various arguments for and against the idea that economic, technological and political factors determine the outcomes of changes in work organisation and technologies. Without wishing to devalue these issues, this chapter attempts to demonstrate the importance of some other issues which can prove instrumental to the successful implementation of new technologies in the industrial setting. For example, there are questions relating to centralisation and decision-making and their relationship to flexibility; there are the more purely psycho-physical issues relating to the specific types of job demands posed by working with new technology, such as vigilance and other forms of cognitive demand; and further, there is the question of what constitutes a "good design" for a job in an advanced technological system.

In Section 6, the chapter addresses some of these theoretical issues by drawing upon case study material reported in the literature, the aim being to give some concrete examples of theoretical principles and outcomes.

Finally, there is a summary, and a brief overview of the state of current psychological knowledge in the area, with some suggestions of likely or desirable future trends in research and applications.