NEW TECHNOLOGY AND HUMAN ERROR

Edited by
JENS RASMUSSEN, KEITH DUNCAN
and
JACQUES LEPLAT

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Foreword

Major trends in technological development increase the demand for systematic consideration of the effects of human errors. Centralization leads to large units in industrial installations bringing with it the potential for large-scale economic losses, damage to equipment, and danger to the environment. Consequently, designers have to consider accidental events of very low probability. Furthermore, there may now be a very short time span from conceptualization of new products and processes to large-scale production, and the design of industrial installations can no longer be based on empirical data from accidents during small-scale prototype operation. The 'pilot plant' which can verify safety targets is becoming a thing of the past.

It follows that any responsible design must then rely on an *ab initio* analytical assessment of the ultimate risk involved in operation. Such an analysis will inevitably include models of human functions, models which will almost certainly be flawed and incomplete, but arguably better than none at all. Even the most rudimentary analysis demands a minimal understanding of function. Just how feasible the whole enterprise may be, including as it must the notorious human factor, is one of the major issues addressed in this book.

It will be essential to understand the error characteristics of all the components of a system which, of course, includes the human beings involved. Information on human error must be expressed with regard to human characteristics, ideally in task-independent terms, not in terms of task failure statistics. Moreover, unlike the assembly-line situation of the 1930s, the design of large-scale, centralized systems must often contend with the potentially drastic consequences of maloperation following a slip or mistake by just one person and, increasingly, legal and economic considerations come to predominate at the design stage.

A related issue which is not always recognized, but which is especially stark in some advanced technologies, is the ethical component of systems design. For example, people should not be caught by irreversible consequences of errors which in their normal life would be accepted as typical features of everyday human behaviour — 'to err is human'. System design techniques are required which, if not 'divine' in their forgivingness, at least increase error tolerance to match their increasing demands. Again the feasibility question looms large — how far off are such system design techniques and, to the extent that they exist, what is entailed in enabling or persuading system designers to use them?

Microcomputers are now extremely cheap and powerful and give designers virtually unlimited freedom in the selection and pre-processing of the data to represent the conditions of the system confronting the user. This introduces great potential for matching tasks to human abilities and preferences, but also brings with it the risk of the user loosing control when unforeseen situations arise, if the design is based on a misconception of human cognitive functioning. In particular, when information is selected and pre-processed, it is important to take account of the different modes of human failure and the kind of information needed in order to recover from slips and mistakes.

Against this background, the study of human cognitive processes and the related error mechanisms has gained rapidly increasing interest over the last decade. Risk analysts have been asking for human error data to be used in the analyses necessary to verify the acceptability of nuclear power and chemical plants. These requests have become more pressing after the accidents at Flixborough, Seveso, and Three Mile Island, for which post-accident analyses have revealed the important role of human beings in precipitating as well as in preventing accidents. On the one hand, engineers collecting plant component failure statistics have started to develop taxonomies of human error data to include in their data banks. On the other hand, control system designers have been asking for data on human cognitive processes and error mechanisms for the design of better control rooms and computer-based support of diagnosis and decision making.

Essentially these are requests for information on human 'mental' processes which, after the early days of *denkpsychologie*, were typically neglected or treated as suspect subject matter for psychology, at least in academic circles. The ascendancy of radical behaviourism, coupled with the burgeoning psychological tests of ability and personality, directed many psychologists either to infra-human species or to sophisticated statistical analyses of correlations. Nevertheless the interest in human cognition persisted. In Europe, it was kept alive notably by Piaget and his associates and by the Cambridge group led by Bartlett. A renaissance of the interest in cognition followed developments in linguistics, and recognition of the potential of computers for information processing. The 'computer metaphor' and similar expressions became common coin, and the distinction between 'hard-wired' and software programs was a beguiling one to the student of human development.

More recently a new 'cognitive science' has emerged, closely linked with the techniques of artificial intelligence. Cognitive science, however, has until very recently been preoccupied with well-specified 'micro-worlds' like games and cryptograms and has not yet proved a fruitful source of ideas for the design of real-life work situations. Some would say that a purely computational cognitive science has still to prove its viability and will only contribute to models of human intelligence or performance by smuggling in psychological data in one guise or another. Nevertheless cognitive science continues to be influential and has the salutary effect of obliging psychologists to take more seriously the intricate problems of human cognition.

The situation is now changing rapidly. Mental mechanisms are acceptable topics for Ph.D. theses, analyses of verbal reports are again being used in fundamental and applied research, and the study of human errors is prominent in university programmes. Moreover the phenomenon of human error is not exclusively accounted for by cognitive mechanisms, but is determined by or related to other proximal and distal factors which may be affective, motivational, or embedded in organizational and social conditions. The field of study is thus truly cross-disciplinary.

It therefore seems timely to bring together representatives from the various professions, with their different approaches to human error analysis, to exchange ideas and to compare methods. With the ever-increasing rate of technological change, it is extremely important to coordinate the resources available to research on human error mechanisms if, indeed, it is to stand a chance of influencing the design of systems still to come.

This book is the product of a workshop with that specific aim in view. To make a start it seemed a good idea to bring together people from Europe working within engineering, psychology, sociology, and systems design, who were all actively engaged in the problem of human error and who shared a common interest in the effects of human error on the use of new technologies and vice versa.

The content of the book reflects its beginnings in a forum of intense cross-disciplinary debate. Each part includes pre-circulated papers of participants, grouped by topic, but inevitably papers in different parts sometimes cross-refer in important ways. Hopefully the introductions to parts have identified at least some of these. Also included are several position papers, some of which were circulated before the workshop and re-written afterwards in response to the discussions, while others were contributed after the meeting.

By organizing the book in this way, it was hoped to go beyond the familiar collection of formally presented conference papers and to get to grips in a modest way with the interplay of ideas in an active group of enthusiastic specialists. The reader may judge whether this was too ambitious.

Acknowledgements

The book is based on papers and discussions from a workshop on 'New Technology and Human Error' and subsequent interaction in the group of scientists representing psychology, social science, and system design. The workshop was the first in a series of meetings of an international, interdisciplinary study group on 'New Technology and Work' (NeTWork) sponsored by Maison de Sciences de l'Homme, Paris, and Werner Reimers Foundation, Bad Homburg.

To facilitate the interaction at the workshop, participants were in advance asked to circulate papers which demonstrated their research approach and findings. Some of these papers have been published previously, and the courtesy of the publishers in permitting the inclusion of revised versions in the present collection is acknowledged.

PART 1

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PART 2

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PART 3

Berndt Brehmer: 'Models of diagnostic judgements'. Reprinted from: *Human Detection and Diagnosis of System Failures*, J. Rasmussen and W. B. Rouse (Eds). Plenum Publishing Corp.

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PART 4

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Jacques Leplat and Jens Rasmussen: 'Analysis of human errors in industrial incidents and accidents for improvement of work safety'. Revised version of: Analysis of human errors in industrial incidents and accidents for improvement of work safety. In: *Accident Analysis and Prevention*, **16**, no. 2. Pergamon Press.

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PART 6

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Part 6: Industrial Studies of Human Error — II

Part 7: Error Sources, Reasons or Causes

Part 8: Review of Discussions

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Part 1: Definition and Taxonomies of Human Error

INTRODUCTION

When the nature and origin of the events called human errors are discussed from different professional points of view, it immediately becomes apparent that the concept of human error is elusive, and that a discussion of the definitions adopted in the various studies is essential, together with a review of the categories used for description and analysis of errors.

To illustrate the relative nature of the concepts involved, contributions have been chosen from an academic psychologist, who focuses on the relationships between categories of behaviour called human errors and features of the underlying cognitive control; a systems engineer, whose concern is with the role of human errors in control of complex installations and their potential for unacceptable effects upon the environment; and, finally, a social psychologist, who looks at the meaning of actions, including human errors, as construed by the individual agent in a context of personal morality and shared social values.

These three authors clearly illustrate the different starting points with their differences in definitions and taxonomies. They were the subject of sustained arguments at the workshop but, with hindsight, the viewpoints are complementary rather than conflicting. Indeed, the differences are such that the approaches scarcely could conflict unless one of them were to claim exclusive validity which, in the light of later contributions, particularly the position papers in Part 7, they do not. Following the interactions during and after the workshop, the different approaches, taken together, constitute a sound basis for matching new technology to the characteristics of human users.

In the course of his descriptions and classifications, Reason makes a distinction between slips and mistakes. Slips occur when a person's actions are not in accordance with the actions actually intended, whereas mistakes are actions performed as intended but with effects which turn out, immediately or at a later stage, not to be in accordance with the person's intended goal. Since Reason's point of view is that of the individual actor, there are no problems, in principle, in incorporating the notion of goal into a definition of human error. A human error is simply an act which is counter-productive with respect to the person's private or subjective intentions or goals.

This route to definition of human error is not so straightforward, in the context of process control, discussed by Rasmussen. Here human errors are typically revealed by analysis after an industrial incident or accident. In this case, the identification of the initial event in the accidental chain of events, including both component faults and human errors, is undertaken from a systems point of view, in order to identify the appropriate counter-measures, be they technical changes or training of personnel. Error is still defined as counter-productive to the goal. But at the systems engineering level there may be several goals, e.g., a production goal, a safety goal, or goals prescribed by regulation or law. Moreover several different people may pronounce on whether goals have been satisfactorily achieved. Consequently, the question of an appropriate definition of human error is necessarily discussed in some detail by Rasmussen. He points out that, in situations where several goals may be articulated, the definition of human errors is equivocal or even fraught with contradiction, and is closely related to questions of operator responsibility and guilt.

In his paper (Chapter 4), Taylor moves this discussion still further in the direction of the question: Are not human errors, as seen from the outside of a person, very likely to be misinterpreted or misunderstood? At best they are only partly understood, unless it is possible to elucidate the meaning of the acts in question to the person concerned. If actions are labelled as error without reference to individual value systems and experience of responsibility, serious problems of safety or error prevention will arise. For prevention of some errors, persuasion in some form is essential, but not likely to be effective without more insights into how users and operators value their transactions with the physical environment and with other humans in the error situation. Even then, Taylor argues, there may be serious limits to the success of measures taken in the hope of preventing human errors. The implications of this view for the design of large centralized systems demand very careful consideration.

Turning now from questions of definition, to the question of classification or taxonomy, it will be clear from the papers that some systematic categorization of the great variety of human errors reported is essential for their proper consideration in systems design, as well as for their scientific study. In the last resort, the taxonomy adopted for classification will often depend on the application.

Thus Rasmussen's paper (Chapter 3) describes how taxonomies generated in industrial systems are often aiming at a classification scheme suited to the