PSYCHOLOGY AND INFORMATION TECHNOLOGY

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BACKGROUND: THE ECONOMIC IMPORTANCE OF THE HUMAN FACTOR

There is no doubt that the economic performance of developed countries will be critically affected by their success in mastering, exploiting and marketing new developments in information technology. Our principal competitors may be advancing more rapidly than the UK in the economic exploitation of information technology. There is unfortunately very clear evidence, over the past five years, that UK manufacturers are taking a declining proportion of both home and overseas markets in IT products. This relative decline appears to have many causes, including short – sighted investment policies and too few resources habitually devoted to technical research and development by both government and industry in the UK. These problems are well known and efforts are being made to solve them. There is, however, considerably less appreciation of the greater efforts which our competitors devote to human factors research in the development of new products, and of the greater care which they take over human aspects of the exploitation of new technology. As a result their products tend to be more 'user friendly' in the sense that individuals feel more comfortable with them and organizations can integrate them more easily into their continuing activities.

With government support the Alvey research programme in information technology has stimulated new developments in design and manufacturing techniques. It has also supported some research on psychological aspects of the man–machine interface and of intelligent knowledge-based systems. Surveys of the work of the Alvey Directorate and plans for a continuation of its work (for example Executive Summary of After Alvey Workshops 6–8 January 1986) suggest that relatively more effort should be devoted to research on the psychological factors limiting the exploitation of information technology.

The prime purpose of this book is to survey what is already understood about human factors in relation to information technology. A secondary purpose is to consider how this understanding can be translated into economically effective action.

In this chapter I discuss possible strategies for exploiting what we already know and for seeking new knowledge about the human factor. Among other things, I hope to convince non-psychologists such as politicians, industrialists, civil servants and engineers that psychologists have important roles to play in the proper development and use of information technology.

Let us consider the phrase 'user friendly' more analytically. There is no doubt it has been over-used and used rather carelessly. Some would like to replace it by the single word 'usability'. Whichever term is preferred, what matter are the ideas which it summarizes. Well-designed technology should be easily understood; easy to use, with a low probability of error; easily mastered, with a minimum of training by the people who need to use it; easy to maintain and to modify; and with virtues which are so manifestly apparent that it will be relatively easy to sell. This will require not only well-designed input and output devices such as keyboards, lightpens, visual displays and robot arms, but also an easily understandable 'logic' in the working of the total system.

That is a formidable list of virtues to be summarized by the single word 'usability' or the single phrase 'user friendly'. But all these virtues are likely to follow if the 'human factor' has been taken into account in the design and use of the technology. When our competitors' products are more attractive, easier to use, more adaptable, less disruptive of other activities, easier to maintain, or, in a word, more marketable than our own, it will be because they have been more successful than ourselves in their use of psychological knowledge and in evaluating the behavioural and organizational effects of their designs.

The application of psychological techniques in the development and use of information technologies is the subject matter of later chapters. In this chapter I consider various ways in which technology may be made more or less user friendly. These range from learning by experience, in a rather amateur fashion, to employing professionally trained psychologists. In this country we have tended to distrust professionals, whether they be scientists, engineers or economists. Fortunately the cult of the amateur is less bigoted than in the past and there is an increasing understanding of the need for adequately trained scientists and engineers in technically innovative industrial developments. However, a surprising number of people, including many scientists, engineers and managers still adopt an amateurish approach to human factors. As long as this attitude continues, our competitors are likely to produce products which are more 'user friendly' and hence more successful than our own.

How, then, should we approach the human factors problem posed by information technology?

LEARN FROM EXPERIENCE

This is a very common strategy. It is like the approach to engineering of the builders of medieval cathedrals. When a cathedral fell down, as they quite frequently did, the next cathedral was made slightly more sturdy. When one stood for a hundred years, the builders attempted something a little more adventurous and delicately soaring. The same approach to bridge building was adopted between Roman times and the eighteenth century. Eventually, Newtonian mathematics was applied to the design of load-bearing structures and it was recognized that professional civil engineers were the best people to do the necessary calculations. As a result, the design of buildings and bridges has changed rapidly and with relatively few disasters.

That comparison is not quite fair since we all learn much more by experience about our own humanity and the humanity of other people than we do about the load-bearing character of different physical structures. We are all amateur psychologists during most of our waking lives, but amateur engineers only rarely. However, no matter how good we become at understanding people in their habitual environments, experience is not so good a guide when we seek to predict how people will behave in novel environments.

The speed of developments in information technology produces new environments, particularly new working environments, more rapidly than at any period in our history. The changes are so rapid that experience is a fallible guide and like the medieval masons we have had our disasters. We shall of course learn from them.

The Swansea Licensing Centre for motor vehicle driver licences was intended to simplify the issuing of driver licences, since all records would be kept in a single computer. This would speed up the process of checking qualifications and reduce the number of errors in the previous system, which depended on meticulous filing of hand-written records. What happened when the Centre opened was almost a fiasco. The delays in issuing licences grew so long that the licensing system became far less reliable than it had been previously. This was not due to any deficiencies in the computer system. The problems were entirely due to the difficulties the staff had in coming to terms with the machine.

Gradually the Licensing Centre has sorted itself out. The staff have learned to cope with the system. The procedures have been simplified. We all get licences valid for 20 years or more and the system now works reasonably well. That experience will help us avoid similar difficulties when other national data bases, such as that for income tax, are set up; but the degree of help will depend on their similarity to the Swansea system and how well we have understood what went wrong. Unfortunately, although well known, the Swansea experience was not well documented and so we may have learned less than we otherwise might have done from it.

The accident at the Three Mile Island nuclear power plant in Pennsylvania was another human factors disaster which could very easily have been much worse. The fault which developed in the system was not very serious and could easily have been rectified if the men in the control room had understood it; but confronted with a vast array of information technology, they misunderstood the fault and by misunderstanding it made it infinitely worse. This particular disaster, unlike that at Swansea, has been very carefully analysed by psychologists, who have made recommendations which, we hope, will very much reduce the likelihood of similar misunderstandings in the future. The control room at Three Mile Island was far from 'user friendly'. This was made abundantly clear in the Kemeny Commission report which has been used and commented upon by many psychologists, for example Reason (in press).

In the past two years many small computer companies have either gone out of business or have been in great financial difficulties. This has happened even to some companies whose products were electronically superb. The usual explanation for their difficulties is that they mismanaged the economic side of their business, running into cash flow problems by too rapid expansion, paying too much attention to technical developments and not enough to financial control. An alternative explanation is that they did not understand their customers' needs well enough. Too many computers were over-sold on the performance which their designers and other experts could get out of them. But they were not sufficiently 'user friendly' to be of continued value to their novice customers once the fashion for computer games had run its course. The small computer companies which are now flourishing are those which learned from the mistakes of their rivals, and have, for example, produced more user friendly word processing packages (such as Amstrad) in addition to having more efficient financial management.

The learning from experience in all these cases is not much more impressive than that of the medieval masons when a flying buttress collapsed. We should be able to do better.

ELIMINATE THE HUMAN FACTOR

The next most popular approach is to regard the human factor as undesirable and to try to design it out as far as possible: hence automated offices and automated factories. Sometimes this approach is successful and the automated process is more reliable and more economical than the human process it replaced. Computer scientists, specialists in artificial intelligence and robotics, systems analysts and a whole host of specialists in new disciplines are devoted to this task of eliminating human error by removing the human from the workplace. These are, however, the very people who are creating some of the disasters from which we are so laboriously learning by experience. There must be something wrong with this approach and it is not difficult to see what it is.

So long as machines are the servants of man and not vice versa, it is, in principle, impossible to eliminate the human entirely. As machines become more intelligent, the problems of making them user friendly will become more acute rather than less so. In the meantime there are very many human processes which cannot as yet be automated and the need for machines to work with and alongside human workers is very obvious. The prime examples are perception (visual and speech perception), speech production and flexible or creative problem solving. People are needed to solve simple perceptual tasks which are still beyond the capacity of a machine. Post office workers, rather than machines, still read our postal codes, although machines do the sorting once the workers have pressed the appropriate buttons. Secretaries still interpret people's speech before putting it into a word processor. People still monitor the performance of even the cleverest machines and decide to switch them off or repair them when they, the people, decide the machines are not working properly.

The strategy of reducing the number of people required to do a job by automating some of their tasks is not desirable in itself. It is only desirable in so far as it reduces the cost of production. There are some human functions which cannot be automated and some which can only be automated by using excessively powerful and expensive computers. Hence the most economic production is likely to be achieved by using humans and machines in an optimum combination, so that all play their appropriate parts doing what they do best.

The strategy of reducing the number of people involved in work requires us to pay *more*, not less, attention to human factors. People cannot be eliminated, and the more unusual the working environment, the greater the problems of human factors design.

PSYCHOLOGY IS NO MORE THAN COMMON SENSE

An almost equally common strategy is based on the attitude that, yes, we need to pay more attention to human factors, but psychology is no more than common sense hiding behind some ugly jargon; hence we can take care of human factors problems without involving those psychologists. Like the other strategies, there is something to be said for this one; but not much. No one would deny that British industry needs to pay more attention, at all levels, to human factors problems. However, the strategy of do-it-yourself psychology is based on a misunderstanding of what professional psychology has to offer and an overestimation of the power of common sense.

The deficiences of common sense are now fairly well documented. We know that common sense is more useful in creating an illusion of understanding after the event than in making predictions before the event. Proverbs come in pairs: 'too many cooks spoil the broth', 'many hands make light work'; or 'look before you leap', 'he who hesitates is lost'. At the level of proverbial wisdom, common sense can explain anything and predict nothing.

Despite these difficulties, common sense is a useful guide in most everyday activities. It is only deficient in relation to rare or novel circumstances. It can be relied upon when our reactions are unthinking and automatic. It is a poor guide when we need to take thought.

In relation to the human factors problems which are posed by information technology, common sense is not only of little help in suggesting solutions, it is equally poor at defining the problems. Occupational psychologists, who are the psychologists most frequently consulted by industry or commerce, have a poor view of their clients' ability to diagnose the nature of a problem. Most clients have a very poor vocabulary for describing the nature of human factors problems. As a result, they usually describe the problem in terms of what they imagine to be the most likely solution to it, for example 'We have a training problem'; 'We have a selection problem'; 'Our workers are not sufficiently intelligent or motivated'; 'These displays are too difficult to read quickly'; and so on. Since every human factors problem can, in principle, be solved by improved design of equipment, or by better selection of workers, or by better training, or by better organization, or by some combination of all of these, it is never appropriate to beg the question by describing a problem in terms of its potential solution. Ideas about the most efficient solution should come after the problem has been investigated and not before.

It is not surprising that common sense is so deficient in analytical concepts and vocabulary. Common sense is a guide to action. It provides a set of reasonably reliable responses to common situations. It is understandably deficient in analysing uncommon ones. Donald Broadbent (Broadbent, Fitzgerald and Broadbent, 1986) has done some very interesting experiments which throw light on this. He has shown that people can learn to operate fairly complex computer games, such as a business game, without being able to verbalize their understanding of the rules by which they run. In other words, the wisdom we acquire by experience gives us intuitive guides to action, rather than the analytic concepts with which to describe and think about the nature of a complex task.

It is not difficult to find real-life examples of the inadequacy of the common sense approach. To take one example from a recent development in word processing. The Macintosh microcomputer developed by Apple Computers Inc. is one of the most 'user friendly' ever devised. However, some of the Macintosh software has deficiences due to the failure of its designers to take account of the structure of human problem solving strategies, which usually work from the particular to the general (bottom up) rather than the other way round (top down). Microsoft Word is a screen-based word processor. It makes full use of the sophisticated Mac interface facilities and when it first appeared it was a long way ahead of its competitors. However, it is unlikely to be a top seller because of the design fault just mentioned (Thomas Green, personal communication). There are invisible formatting characters inside the text. If the user makes an overall formatting change, such as asking for the justification of the right-hand margin, then the system makes sensible but unpredictable alterations in the invisible characters, so that, for example, the positioning of equations or headings in the centre of a page may be altered and these changes are then difficult to adjust. In contrast, MacDraw, a Macintosh graphics programme, allows the user to make trial and error corrections of elements in the program, without altering its other features. Similar errors have been made in the design of data base software and in integrated office systems. These errors could have been avoided by the application of comparatively simple psychological principles. When stated these may seem mere common sense, but only after the event.

In general, and rather ironically, the military pay more attention to human factors than does civilian industry, but even the military have experienced numerous human factors foul-ups, for example in the monitoring and planning of the Vietnam war, and in trials of new technologies in which the commanders' strategies have been determined by non-existent threats detected by radar and other remote sensors. Many failures of this type are blamed on the person operating the equipment. 'Pilot error' is often invoked when the most obvious failure is one of design.

To show that psychology transcends common sense in being able to make predictions about the future as well as explain the past, I will now predict a future difficulty before it occurs. Many applications of information technology are dependent upon the development of expert systems. These systems, which are a dominant technique in 'knowledge engineering', are intended to replace a particular form of expertise, for example in medical diagnosis, or in computer-aided design, or in the control of a chemical plant, usually by a series of if/then statements known as a 'production system'. There are two unsolved problems which limit the usefulness of expert systems. These are:

1. One of the techniques used to aid the construction of an expert system is 'knowledge elicitation', that is the self-characterization, by human experts, of the nature of this expertise. This often takes the form of decision rules which can be incorporated into a production system; but many of the conscious rules used by human experts only work because they are embedded in a framework of tacit knowledge which the expert may not be able to verbalize (Broadbent, Fitzgerald and Broadbent, 1986). Hence 'knowledge elicitation' may not be such a short cut to the development of expert systems as many people now imagine.

2. Simple production systems are relatively easy to run, since there may be only a limited number of ways in which one can procede through the sequence of if/then statements. However, before they become useful, they become large and unwieldy. They can only be controlled by sophisticated planning systems which are not yet so well understood. This limits the size and power of expert systems.

These difficulties are unlikely to be completely solved in the near future. Hence, expert systems will not do some of the things which people currently expect of them. However, there are many things which they can do, provided we understand their limitations and the type of human activity which they can replace.

WRITE A HANDBOOK OF HUMAN ENGINEERING

This is a good idea, the best yet. Moreover, it has already been done several times, most recently by three psychologists, Card, Moran and Newall (1983), who summarize very cleverly all the features of human perception, motor skill and problem solving which they consider essential for the design of word-processing systems. This book is very much appreciated by designers, since it attempts to summarize its data in a form which engineers find congenial. However, it does have some deficiencies which those using it (and any other human factors handbook) must be aware of and take into account.

The first is that the amount of psychological knowledge summarized is extremely small, but the application of this knowledge is extremely complex. The knowledge is summarized in 10 principles of operation of the human information processing system. These are stated on *one page* of the book. Seventy-eight pages are required to justify and explain these principles, while 332 pages are needed to explain their application to the design of text editors. This is not quite as bad as it sounds, because the techniques of task analysis and problem solving which are used can be generalized to other issues in information technology. Nevertheless it is impossible to take any single piece of information from the book and apply it to a design problem without being aware of the techniques and skills needed to apply that information successfully.

Or, to put it another way, such a handbook is likely to be much more useful to an experienced psychologist than to an engineer who is less well trained and less experienced in human factors work.

The second deficiency in the book by Card and colleagues is that it contains very little on problem solving or learning and nothing on psycholinguistics, or instruction, or explanation, or individual differences or social factors. In other words, there is a great deal of very important psychology which is not covered. A more adequate human factors handbook would have to be very large indeed.

USE HUMAN FACTORS STANDARDS

This is another good idea. If, during the design of a product, there is a shortage of good human factors or psychological expertise, then the design engineers can be helped by giving them certain psychological standards which the product must meet. These would be comparable to the standards of physical performance which are in the specification given to any design team. Just as the physical standards help to ensure that the technology will work in its physical environment, so the human factors standards could help to ensure that it will operate satisfactorily in its human environment.

Human factors standards are most familiar in relation to product safety. It is ethically undesirable to damage the human user by excessive radiation, or by poisoning or by creating eye strain or backache. Hence the need for health and safety standards. The same approach can be used in relation to economic performance. It is economically undesirable to create difficulties for the human user because the visual displays are difficult to interpret or because the logic of the system is difficult to understand. So standards which demand clear displays, transparent logic and easily learned operations could have very beneficial economic effects.

Unfortunately, it is impossible to solve all human factors problems by the use of a small set of design requirements. The reason for this is fairly obvious, since the design of a system, including the form of its interaction wih human users, must depend on the nature of the task and on the relative roles given to person and machine in performing the task. The standards must be adapted to the circumstances.

We might be able to overcome this difficulty by producing long lists of desirable design characteristics for most imaginable tasks and strategies for performing the tasks. This has never been attempted in a civilian context, because it is a mammoth task, and, even so, works only in relation to highly predictable developments in technology. This approach has, however, been used in a limited range of military contexts.

An alternative approach would be to develop ways of adapting the standards to the needs of the situation. This is the method which has been recommended in discussions with the Alvey Directorate. What follows is based on the results of a workshop on human factors standards sponsored by the Alvey Directorate.

It is helpful to distinguish three types of human factors standard: product, performance and procedural.

Product standards like those already described, specify concrete characteristics which are desirable. These may be used by designers as an aid to design, or by buyers when comparing the characteristics of alternative products.

Performance standards may be used when product standards are not available. Instead of specifying the characteristics of the product, they specify performance characteristics such as speed of operation, ease of learning or flexibility of use, which must be achieved when the technology is used by the kind of people who will be expected to use it when it goes into operation. Performance standards may be used by designers when assessing the performance of a prototype or by buyers when choosing between products. Since both product and performance standards must be appropriate to the task, to the technology and to whatever strategic mixture of human and technical intelligence is adopted, we need a third type of standard to ensure that both product and performance standards are properly developed and evaluated.

Procedural standards specify desirable or essential features of the procedures used by the designers in developing products. They will include such things as the need for a proper task analysis before specifying what the new technology will be asked to do, the development of prototypes whose performance can be assessed, the production of effective documentation and careful introduction of the product to the market with follow-up and evaluation.

Figure 1 shows one procedural sequence which ought to be specified as a procedural standard. It is a description of the design process, loosely based on Christopher Jones (1970). It describes a design sequence which can start from an appreciation of commercial pressures and proceed in a systematic fashion to respond to these pressures. A procedural standard of this kind is not a specification of a formal system, but an *aide-mémoire* to ensure that no essential features of the design process are omitted.

The sequence of activities represented in Figure 1 can be regarded as the result of a task analysis on a well-conducted design process and

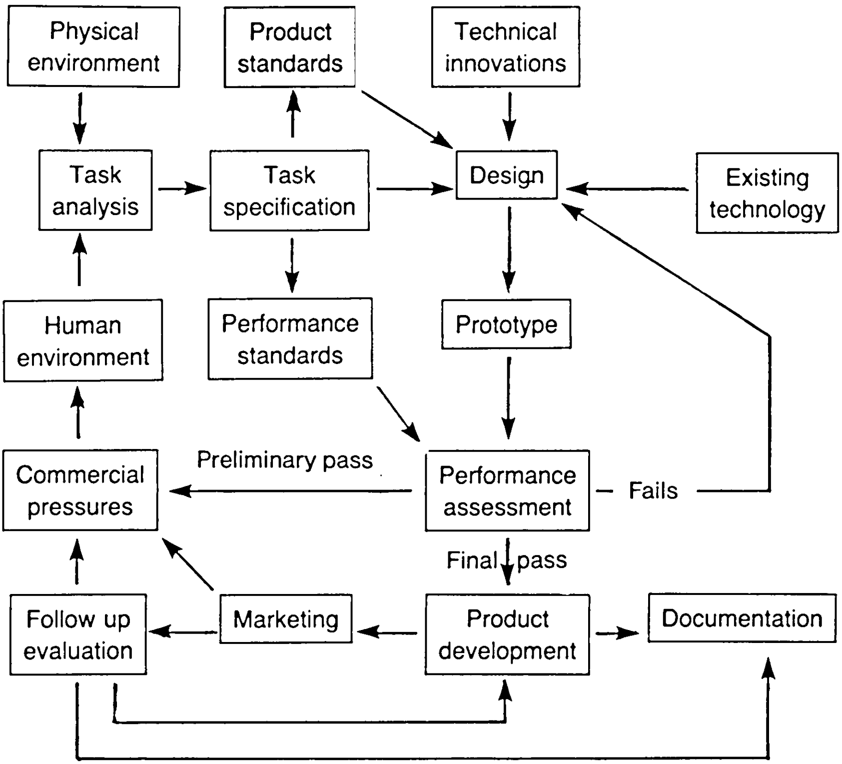

Figure 1. The design process (based on Jones, 1970).

as an *aide-mémoire* or heuristic which will help the designer to consider all important aspects of the design process.

This view of design shows its relationship to the total process of developing and marketing a new product. It has the advantage of showing the related roles of different kinds of specialist, including management (involved in marketing and assessing commercial pressures), engineers (involved in prototype and product development and the deployment of existing technology), scientists (introducing technical innovations) and psychologists (involved in task analysis and performance assessment). Most of the activities shown in Figure 1 involve the collaboration of more than one specialist.

There are several loops in the process which may receive too little attention. For example, one may go straight from *commercial pressures* to *task specification*, to allow *design* to be dominated by *technical innovation*, or skimp the process of *performance assessment* on a *prototype*. These are all false economies.

Many developments are driven by new technology rather than by an appreciation of commercial opportunity. This does not require any reorganization of Figure 1 since, no matter how innovative the technology, it must be fitted into an economic niche if it is to be successful.

The procedures set out in Figure 1 are of course a considerable simplification of the design process. The cycle – *design* → *prototype* → *performance assessment* → *design* – may be traversed several times. Initially the prototype may exist only in the designer's head, then in outline form on paper, then in several versions of a partially implemented simulation or prototype, before the final version is built and tested. The earlier, cheaper iterations ensure that there are fewer problems with the final version.

Figure 1 shows both product standards and performance standards arising out of the task requirements, which in turn are derived from an analysis of the task to be undertaken. One of the dangers of adopting ready-made product or performance standards is that they may encourage the designers to spend too little time and effort in the task analysis on which the task specification and appropriate product and performance standards should depend.

TRAIN ENGINEERS TO UNDERSTAND HUMAN FACTORS

A handbook of human engineering or the specification of human factors standards will, in themselves, give engineers a better understanding of human factors. But, as my discussion of these two strategies shows, it is very difficult for engineers to make full and effective use of either, because their training does not prepare them to do so. A recent survey of courses related to information technology (for example computer science or electrical engineering) has shown that very few of them contain much study of human behaviour. As one of the respondents said, the problems raised (by IT) are dictated 'solely by the physics of the situation'. The view of many physical scientists that all technical problems can be solved by the methods of physical science is not only a symptom of the cultural disability which inhibits our capacity to take economic advantage of our scientific achievements. It is also a powerful barrier to the development of a better understanding of human factors problems, either by education or as a result of experience.

This barrier could be overcome and indeed it must be overcome. But we must not overestimate what could be achieved by inserting more teaching of human factors and more study of human behaviour into IT training and education. It would and should give engineers an understanding of the nature of human factors problems, the methods which can be used to investigate them and the types of solution which are available. It would enable them to make better use of human engineering handbooks or of human factors standards; but it would not make them experts at investigating and solving human factors problems. Psychology and ergonomics are full three-year courses at undergraduate level and postgraduate training is considered essential for most jobs in professional psychology. To expect engineers to act like professional psychologists after taking psychology as a very minor part of their professional training is frankly dotty. It is even less sensible than it would be to expect psychologists to act like professional engineers after taking electrical engineering as a minority element in their professional training. A psychologist with a background in mathematics and science could, in fact, make reasonable use of a course in electrical engineering, at least enough to make good use of the available handbooks and physical design standards. The information in physical engineering handbooks is less context-specific than that found in human engineering handbooks, and physical design standards do not usually need to be changed for every small change in the nature of the task or the type of design chosen.

Despite the comparative ease with which one can gain access to design specifications in engineering, these specifications are more effectively used by properly trained engineers than they would be by someone with only a sketchy training. The case for employing people who are properly trained in applied psychology is even stronger.

ENCOURAGE COLLABORATION BETWEEN ENGINEERS AND USERS

While psychologists and ergonomists may claim to understand the human factors involved in making optimum use of information technology, the users of IT have an even more intimate understanding, even though their understanding may be less articulate or analytic. Many people think that by putting engineers directly in touch with the users of technology, we can cut out the middleman, in this case the psychologist.

There is no doubt that engineers can become more realistic and may even be inspired to produce more creative and effective technology as a result of direct contact with the users. It is a highly desirable form of training or experience for any engineer. But again we should not expect to solve all our problems this way. The users of technology suffer from three deficiencies as informants about the human uses of information technology:

- their experience is with existing technology, not with new inventions
- they have difficulty describing simply what they have learned from their experience because they lack the necessary vocabulary and concepts
- their testimony is distorted by the well-known effects of expectation, prejudice and motivation on perception and memory.

Engineers, even when given some training in psychology, suffer from related deficiencies as elicitators of information from users. These are:

- they lack the theoretical understanding needed to extrapolate from present experience to future possibilities
- they will waste a great deal of time because they do not have experience of techniques for extracting information from informants
- they do not know how to extract reliable information from several unreliable sources using the techniques which Newell (1972) called 'converging operations'. This involves the use of very

different techniques such as observation, interviews and diaries to disentangle valid from ephemeral testimony

- ☐ they are poorly informed on techniques for studying 'statistical' effects.

These deficiencies create a mismatch between the type of knowledge possessed by users and the ability of engineers to take advantage of it. It is precisely because psychologists and ergonomists have a theoretical understanding of human behaviour and experience in techniques for improving their understanding that they are desirable members of any design team. Middlemen they may be, but it is dangerous to eliminate them. This leads us to the final strategy, which we regard as the most effective.

EMPLOY PSYCHOLOGISTS AND ERGONOMISTS IN DESIGN AND EVALUATION

Figure 1 shows where psychologists can contribute to design and development. They are better equipped than anyone else to do task analyses before task specification; to develop human factors standards for products and performance; to do performance assessment on the prototype; to develop documentation; and to do follow up evaluation on the final product. They are very valuable members of any design team and can contribute usefully to the development of marketing strategies.

Thirty years ago, I was a very junior member of the 'High Performance Research Team' at the Institute of Aviation Medicine. Farnborough. Our task was to investigate the human problems of flying a new generation of high performance aircraft. These imposed greater physiological strain on pilots, but they created even more difficulties of a psychological kind because of the reduction of the time available for many crucial decisions and the complexity of the new instrumentation. As an afterthought, our team was expected to study these problems and suggest ways of overcoming them. We were able to suggest some remedies, such as the redesign of some instruments and the use of auditory rather than visual warnings for some purposes; but most of the ideas we developed could not be implemented because they were difficult to fit into the existing structure. The strongest impression I gained from this experience was the sheer folly of treating the human factor as a 'bolt-on goody'; something which could be done after the engineering problems had been solved. It is rather dispiriting to find myself still preaching the same sermon to the unconverted or only partially converted.

Ergonomists and psychologists are now involved in the design of aircraft, if only to help meet safety requirements; but whenever a new technology is developed, we seem to slip back into old habits and fail to involve psychologists until there are a number of embarrassing human factors errors. An exception to this rule was the American programme to put men on the moon. NASA employed large numbers of psychologists in the selection and training of astronauts and in the design of the lunar modules and the lunar module simulators. As a result, the astronauts were able to operate in a totally novel environment without any serious human error. There have, of course, been human errors in the space programme, but these have involved controllers and administrators rather than the astronauts themselves during flight.

The space programme is sometimes justified because of the technological 'fall-out' which has benefitted other aspects of industry (non-stick pans!). In my view the most useful lesson is the need to involve psychologists in any ambitious development programme.

This chapter began by claiming that our economic competitors were better than us at solving human factors problems. The Americans, the Japanese, the Germans, the Scandinavians and the Dutch are all more likely than us to involve psychologists in the design process. If the arguments presented in this chapter are valid, this is not an unimportant observation. Their better use of applied psychology is likely to be a crucial factor in their better economic performance.

WHAT KINDS OF PSYCHOLOGIST ARE EQUIPPED TO WORK ON IT?

Not all psychologists are, of course, trained to work on problems relevant to information technology, but a surprising number are. All psychologists will have received a basic training in cognitive psychology, which is now regarded as the intellectual core of most degrees in psychology. Moreover, just as engineers receive some training in psychological issues, many psychologists are taught some computing and some aspects of artificial intelligence. Of particular interest here are those who have taken joint degrees with computer science or cognitive science.

Many psychologists, after their first degree, go on to do research in cognitive psychology and much of this research is relevant to information technology, being concerned with such topics as the limitations of human attention, the structure and limits of memory, strategies in human problem solving, visual search, manual skills, perception and recognition, learning and instruction. Research in social psychology may also be relevant when it is concerned with such topics as reactions to innovation and change, negotiations, the social organization of work and socio-technical interactions. The study of stress by physiological psychologists may also be relevant, since many new technologies do create stress and the safest ways to counteract stress are psychological rather than medical or pharmacological.

Other psychologists specialize in the psychology of the work-place and act as consultants as well as researchers in this field. Occupational psychologists and ergonomists are trained in very similar ways and do very similar work. The ergonomist may know a little more about anatomy and physiology and the psychologist a little more about social factors, but these differences are very slight. These people are particularly appropriate to act as members of a design team, as described in Figure 1. They will be well trained in the relevant techniques of task analysis and in methods of evaluation, either of prototypes or of final products. They will also be knowledgeable about selection, training, organizational aspects of work and basic equipment design. Being broadly trained in dealing with applied problems, they are the most appropriate people to advise on the nature of the human factors problems likely to be encountered in the design and deployment of intelligent information systems.

It is not difficult to find out what sort of help designers can get from human factors experts. There are now many books on the psychology of human computer interaction which are more extended in scope than the handbook written by Card and colleagues (1983). This book is itself one of these. Smith and Green (1980) and Weinberg (1971) are earlier examples.

SUMMARY

To be efficient and economically successful, information technology must be acceptable to the people who will use it. It must be easy to use, and be understandable rather than mysterious, so that it can be used flexibly and reliably and be easy to maintain. It must facilitate the development of good working practices and organizational structures. In other words, information technology must be 'usable' or 'user friendly'.

These virtues will not be achieved unless proper attention is paid to the human factor in implementing new technology. If this is to be done in an efficient and professional manner, psychologists and other human factors experts must take part in the design process. When engineers design for engineers it is not surprising that other people have difficulty in working with their products. And selling them.

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