Man-Computer Interaction—The Contribution of the Human Sciences

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An introductory survey is presented of the possible contribution of the human sciences to man–computer interaction, based upon a full review of the relevant human factors literature which is to be published. A possible taxonomy for the field is proposed founded on broad divisions of the human sciences problem areas and of the types of computer systems and services. Using the taxonomy as a framework, some examples of relevant human sciences work and some problems and research needs are discussed.

1. Introduction

The advent of multi-access time-sharing computer systems is leading towards 'instant computing', and the concept and the reality have now existed long enough to allow an appraisal. For instance, at the design philosophy level, enough data are available to support the view that both the man and the big computer are highly sophisticated central processors but, when linked together for interaction, they are joined by somewhat limited communication channels. Again, at the more practical level, user attitudes are beginning to present problems; for instance it was reported recently (German 1969) that large numbers of the British public expressed some concern when faced with alterations on their cheques to accommodate bank automation.

The purpose of this paper is to try to clarify, at least in the author's mind, some of the problems, terms and areas of work by suggesting a framework for classifying the whole field of man–computer interaction. The second aim is to suggest the main areas and problems for which the human sciences can or should be able to make a significant contribution.

2. Background

Man–computer interaction has come to be spoken of widely as synonymous with on-line, multi-access, time-sharing computer systems, mainly because these have been the first to provide large computer power with rapid, often instantaneous, response. In such systems several concurrent users are given direct contact, by suitable time sequencing, with the whole computer and thus have its entire capability at their disposal without having to work via the traditional attendant specialists (the programmer and computer operator). The early growth of this field was considerably stimulated, and has been described, by Licklider (1960, 1963, 1965). A very useful introductory book on the subject as a whole has recently been written by Wilkes (1968). The growth in use of such systems has been described by Glauthier (1967), and the experiences and attitudes of business management from this increasing usage have been reviewed by Allen (1969), based upon a survey of nearly 100 U.S. companies.

However, such systems are by no means the only situations which involve significant interaction between men and computers. For instance, it is not necessarily the case that interaction is the most rapid and direct, as has usually been suggested, with an on-line time-sharing system. In the last few years the concept of very fast batch-processing has developed, with turn-round times in the range of seconds up to, say, fifteen minutes, with data and program handed over by the user either by hand at the computer room in the conventional way or via a remote terminal. The comparison of the time-sharing and batch methods is discussed briefly in Section 4.2. Further, the interaction between men and computers is not yet, and probably may never be, limited to the usage of the computation facilities; there are also the areas of operational control of a computer installation, development of improved facilities by devising new software systems and new languages, as well as the mundane but vital aspects of maintenance and fault-finding.

Therefore, while accepting the phrase man–computer interaction as a useful shorthand to refer to the multi-access, on-line method for providing immediate computer service, this term should by no means be restricted to that aspect. A more appropriate, and also widely used, meaning of the term man–computer interaction is in the sense of very direct, close-coupled, computer usage, and this interpretation seems much more useful and acceptable. However, for this survey of the field, the term will be used in its widest sense and all significant ways in which men may interact with computers will be included, with the aim of emphasizing those aspects and variables which are dominant for the human side of the man–computer equation.

3. Suggested Taxonomy

3.1. *Basic Considerations*

Since, then, this paper is to mention the whole field of man–computer interaction, rather than to consider only the multi-access time-sharing area, and since some problems and needs are already evident, it seems desirable to suggest a taxonomy to try to structure the field. As a basis for this, three general considerations seem relevant.

The first to be noted is the type and range of computers involved. These consist of

(*a*) electronic digital computers of all sizes;

(*b*) electronic analogue computers of all sizes;

(*c*) hybrid machines with both analogue and digital elements.

In this discussion, all mechanical, optical and other special machines are omitted. Further, the main attention will be given to the general-purpose machine; therefore, this analysis does not intend to consider specific machines such as military airborne computers, spacecraft systems or aircraft simulators for training, nor the specific applications of general machines, such as for industrial process control, etc., even though these all have major human factors problems on which significant work has been done in a number of cases (e.g. Voas 1961, Grodsky 1967, Mudd 1968; Shackel *et al.* 1967). However, the taxonomy proposed is in fact also applicable to the broad problem areas of such special cases, and could equally be used as a checklist for any problems when concerned with a special system or application.

A second dimension is the broad range of situations where men and computers do interact. These can perhaps be divided into four groups.

1. Small machines, either digital or analogue (e.g. simpler versions of the digital PDP 8, Modular 1, etc., and the analogue EAI TR 48, EMIac 2, etc.) or hybrid, where the operator of the machine is also, usually, the person using the computation facilities provided.

2. Large installations—service aspect—that is, where the work is concerned with the generation of a computer service and where man–computer interaction is involved in the control of the system, the routine operation of the computer, maintenance, fault finding, and the preparation of input material.

3. Large installations—usage aspect—that is, for digital computers on batch-processing, where the man–computer interaction for the user involves handing over his input material, either in machine-ready form or for input preparation, and then collecting the output at a later time. On the other hand, if the computer is a general-purpose analogue system, or a large hybrid, then often the operators are also the users, or the problem has to be worked out at length by the user with the operating staff, who will then set up and run the work. This is because the types of problems for which these machines are needed tend to be of a specialist nature, and also the economical form of construction of a general machine for such problems leads to the setting up and running of each new problem usually taking some considerable time. Special cases, at present, are computer aided design and computer aided instruction where, although in effect the connection is by remote entry (see next section), the computer is often in the same building or even in the same room. The man–computer interaction tends to be more typical of the remote entry situation, but the nearness to the computer and its staff may often lead to time savings when usage problems arise or experiments are being run.

4. Remote entry—this is the situation, often referred to as man–computer interaction, where the user is not concerned with the computer operating regime at all, unless system faults occur, and has the impression of direct usage of a large computer facility with few operating control problems and, above all, direct program input and running. Certainly this is the intention, and it is usually achieved, but also still too often there are annoying service faults and delays. It is important to note that the user is not necessarily on-line directly into the computer processor; his work can be fed by remote entry through his terminal into a queue waiting for batch-processing, with the results available after a time interval. With the latter system, it is somewhat more difficult to achieve immediate response (i.e. less than one second, say) to an input signal which is a fundamental part of the user's program.

The third main factor is the range of relevant human science knowledge. The human factors problems which arise are many and diverse (cf. Nickerson *et al.* 1968), ranging from simple ' knobs and dials ' questions to such complex aspects as language designs and criteria for comparative evaluation of different systems. Certainly, for the range of problems already evident, some data exists and the research methods and approach from the whole broad spread of ergonomics, and also from some of the social sciences, are clearly relevant.

It is true that there are relatively few studies of direct application to immediate design problems, but more have been done than are perhaps well known (because they are so scattered) and more of the general human sciences data are applicable than might be realized by system designers. A literature review has been prepared to try to assemble the relevant references (Shackel and Shipley 1969).

3.2. *Classification*

Based on this review of the literature some sub-divisions can be suggested for the possible human sciences contributions. The sub-divisions proposed are: system aspects, the man–machine interface, human aspects, environment, and some special usage areas involving problems on which a human sciences contribution should be particularly relevant.

It seems appropriate to repeat these sub-divisions, with some small variants, under two general headings according to whether the man is primarily involved with the generation of the computer service or with the usage of the computation facilities. Further, it seems appropriate to divide the areas of usage into three broad classes corresponding to the type of computer system involved.

Thus the proposed classification can be tabulated in a matrix, see Table 1. To clarify these divisions, let us briefly consider each in turn together with the types of problem for which human sciences knowledge is envisaged as potentially useful.

Table 1. A suggested taxonomy for human sciences contributions to research and development in man–computer interaction

	Small machine	Large installation	Remote entry	
Generation of computer service				
1. System aspects		*		
2. The interface	*	*		
3. Human aspects	*	*	*	
4. Environment		*		
Usage of computer facilities				
5. System aspects		*	*	eg. languages response time
6. Hardware interface	*		*	eg. keyboard layout
7. Software interface		*	*	eg. message verbosity
8. Human aspects	*	*	*	eg. learning speed
9. Environment			*	eg. noise, space
10. Special usage areas and problems		*	*	eg. The Public Management information systems Evaluation methods and criteria

* Although a human sciences contribution is relevant to all these areas, those considered of particular importance and of likely cost-effective value are noted with an asterisk, and some examples of problem dimensions are noted in one sub-column.

3.2.1. *Generation of computer service*

System Aspects

These aspects arise from or depend primarily upon the characteristics and performance of the computer system itself, and have major implications for, or influence on, the humans involved. For instance, with large installations providing a service to many users, there is a major organization and human relations problem in coping with the many enquiries about system performance and facilities, and in handling complaints of loss of material, etc., arising from system breakdown.

The Interface

This embraces all the hardware and software features with which any humans have to interact. Attention is needed to such features as optimum design for control by the operators and for rapid fault finding by appropriate staff, and the provision of good job aids to assist with maintenance and fault finding.

Human Aspects

These aspects depend upon or are optimized primarily on the basis of human variables, and do not involve much change in the system features. Significant problems can arise in such aspects as programmer selection, training of maintenance staff, performance and social and personal difficulties due to shift work on a 24-hour rota, and the organization and control of work for both management and staff. Problems of the last type may be intensified, at times, by stresses arising from the high work-load and time pressure which often occurs, and also by the relative youth and incomplete maturity of many staff in this field.

Environment

In many installations, even with current systems, a carefully controlled environment is required to increase equipment reliability, and this often causes, as ' spin off ', the human operators to have a pleasant summer's day situation (about 70°F and less than 40 per cent relative humidity, ideal for comfortable working without a jacket). On the other hand, lighting and particularly noise are not always so well controlled. The rate of growth of installations and computers is such that improvement is occurring by trial and error, but these are routine problems which can be handled easily with straightforward ergonomics advice (e.g. Beevis 1964, 1966).

3.2.2. *Usage of computer facilities*

System Aspects

As before these are aspects which are often dependent on and optimized by computer system criteria but which nevertheless have major implications for human interaction. Two major problems are, of course, language and response time. Both of these are major research areas.

Hardware Interface

Much research and design work remains to be done to produce equipment optimized for widespread use by people with widely differing levels of skill, intelligence and understanding. Considerable improvements in design should be possible to increase speed and reduce errors by the human user.

Software Interface

By this term is meant those parts of the man–machine communication medium which are not hardware, and which usually can be varied by program control; for instance, such aspects as the format, layout, etc., of displayed material and the logical progression and relative verbosity of a sequence of man–machine messages. By definition, we are not concerned with the programming language in use, which is a system aspect. The subject here is the grammar, syntax and other language aspects of the interaction process between man and machine during the actual running of programs, or is the layout, etc., of forms which have to be filled in by users from which input data is prepared. For instance, the layout of financial reports and tables of manufacturing accounts data, prepared for a manager, would be one of the software interfaces between a management information system and the management users. Again, questionnaire forms are a software interface and need to be designed both for easy filling in by, for instance, the public and for easy reading by card-punch operators in the data preparation office.

Human Aspects

As before, these depend primarily upon human variables, and should be optimized on that basis, but they may have an influence upon system considerations also. For instance, the training of operators and social group factors, among the operators in a large installation for batch-processing, will certainly affect their performance. Again, there will be large individual differences in the speed of learning to use effectively a remote entry time-sharing teletype terminal, and this must affect the likelihood of continued usage and the cost–benefit ratio for the slower users.

Environment

Here, of course, the environment is very much under the control of the individual user. However, two factors should be mentioned. The noise of a teletype is quite obtrusive and, until quieter machines are readily available, some suitable treatment to minimize noise inside and outside the room is often desirable. Second, most users during remote entry need several reference books and papers to hand, and attention should be devoted to making a suitable work-station around the teletype terminal.

Special Usage Areas and Problems

These are aspects of man–computer interaction involving particular problems or applications where the human sciences may have an especial contribution to offer. The following seven topics are suggested as coming within the category at present, but the list is subject to debate and is not offered as conclusive.

1. *Variability of the human user.* It will be vital to build much more flexibility into programs in the future, to enable users to alter and re-program as their needs and their sophistication develop. Also, programs, and perhaps languages, will need to be designed making allowance for the different rate of learning of different users, and particularly allowing for the wide range of users from housewives to top scientists.
2. *The Public.* There are many problems here, including the design of forms suitable for public use with minimum errors and yet also suitable for mark-sensing or optical character recognition. Again, there are all the social science aspects involved in changes to facilitate automation (cf. German 1969). A standard solution at present, of course, has to be to

provide a suitable trained ' buffer ' between the public and the computer such as the reservation clerks in airline reservation systems.

3. *Computer aided design.* There are problems of matching to human creativity without constraining it, and providing flexible and appropriate displays.
4. *Computer aided instruction.* Again, matching to human variability, particularly in learning speed, will be essential and may be difficult.
5. *Management information systems.* The importance of industrial psychology and industrial sociology, particularly in relation to organization aspects, is perhaps only beginning to be realized.
6. *Privacy of personal information.* This subject is beginning to receive much attention and debate (e.g. Malik 1969). Some research by social scientists, and perhaps by political scientists and social philosophers, is needed.
7. *Evaluation methods and criteria.* The importance and the difficulty of adequate evaluation studies is beginning to be realized in the computer field. Because nearly all the evaluations are essentially trials with humans, the experimental methods of the human sciences must be used if validity is to be ensured.

4. Some Examples and Problems

Within the compass of this paper it is of course not possible to be comprehensive, and only a few examples of work done or of important problems can be mentioned in some of the areas proposed for consideration. The discussion which follows is sub-divided by the other dimension suggested in the classification scheme, that is the class of computer system. However, it should be noted that these three classes are not exclusive and, for instance, the generation of computer service under the heading of remote entry largely overlaps with the same section under the heading of large installations.

4.1. *Small Machines*

Over the years there has been some attention to the routine ergonomics problem of interface design (Shackel 1959; Lincoln and Konz 1964). However, it is believed that the application of ergonomics data during machine design is still not a routine matter for all companies, and this is evident in the interface aspects of some machines.

Under the heading of human aspects, the question of maintenance and fault finding particularly comes to mind. The user of a small machine often does not have skilled technical help available to deal with faults, and it is suggested that much more attention should be given to the provision of fault-finding routines, more comprehensive diagnostic guide books, and similar job aids.

4.2. *Large Installations*

System Aspects

From the range of questions under the heading of system aspects, the configuration of the computer system itself seems the most appropriate to discuss. For a time, the debate (if not heated argument) on the relative merits of time-sharing usage versus batch-processing tended to concentrate on the computing system costs, such as job-swapping overhead etc. and to obscure the essential human factors aspects. In this context the underlying variable for the human is probably system response time, and the important comparison criteria are probably:

1. total man-hours and thus costs to finish the task concerned;
2. total computing time and costs similarly; and
3. subjective preference rating and benefit assessment by the user in terms of how much extra he would pay for any features he prefers.

Only on these grounds, it is suggested, can a valid cost–benefit comparison be made.

Sackman (1968) and Sackman and Gold (1968) have reviewed the various studies of this question, and have concluded that so far no final judgment can be made; batch seems more efficient for economical machine operations, whereas time-sharing is more effective throughout all stages of human problem solving. This result appears valid for conventional batch-processing, and also there seems to be some advantage for interactive time-sharing over fast batch-processing; but they consider the data are still inconclusive and that critical experiments are needed to compare time-sharing and fast batch methods. Their papers, particularly the latter, are excellent surveys of the problem and the underlying psychological factors.

In the only later study found, Adams and Cohen (1969) have compared time-sharing and ' instant ' batch-processing, with eight subjects on a programming course. Their objective measures show no advantage for either method, partly because of the large individual differences between the subjects, but they report that the students preferred the instant batch system and continued to use it for the rest of the training period, even though both were equally available. However, the validity of and inferences from these subjective results must be viewed with caution, because of major differences in performance and facilities between the two computer systems; the time-sharing one was the standard General Electric telephone service, and the batch processor was the ' in house ' C.D.C. 6600 machine, with an on-line plotter also available. Moreover, seven of the eight subjects ran the first program they had ever written in the batch-processing mode, and one may speculate a significant psychological effect from this early history.

Thus, the time-sharing versus batch-processing debate continues. However, the importance of the human variables is now fully recognized, and the need for properly controlled experiments to ensure valid results from human subjects is also being realized.

The Interface

With regard to the interface, a design study with ' before ' and ' after ' illustrations of the operating console and other aspects, for a large digital computer, has been reported by Shackel (1962). While no other studies have been found in the literature, it is known that specialist human factors attention is given to this design area by several of the major computer manufacturers. On another interface subject, the topic of questionnaire design for easier data preparation, Pinkerton (1969) has described how, in the early years of the Lyons *Leo* computer system, it was found that errors in data preparation in the card-punch office were about three times less, for the forms which had been carefully designed within the Lyons organizations, than for forms produced by other companies using the *Leo* computer facility. This was not a question of forms designed to suit the data preparation, but merely a question of clarity in form design for the user, which thus also laid out more clearly the information which the card-punch operator had to find.

Human Aspects

Under the subject of human aspects, a number of problems exist with important practical implications. The whole area of selection of programmers and systems analysts is by no means yet established on a scientific basis. Some recent work by the National Institute of Industrial Psychology has clarified the selection problem somewhat, but further work is still needed on this and particularly on the evaluation of training. Another major problem area, for which no answers and few guidelines yet exist, is the question of achieving an optimum match between the man and his tasks and responsibilities in a complex computer network, such as is established by the U.S. services for detection, command and control in the strategic air defence field. Jordan (1962) analysed and reported problems of this type in the SAGE system, but little work has been done since to follow his lead and study the conditions and selection criteria which would enable a good match and ensure high motivation.

Special Usage Areas and Problems

A related subject, but one which can equally be classified under the special usage area of computer aided design, is the question of resistance to change and the psychological and social factors which tend to inhibit rapid advance. Chasen and Seitz (1967) particularly discussed this aspect in relation to the growth of man–computer graphics, and said that " therefore, there is a great resistance to change in a methodology regardless of whether it is right or wrong. Most of us prefer to solve problems as they have been solved in the past. When people are busy and concerned with deadlines, they prefer remaining under a known pressure to risking the loss of time of an unknown (to them) alternative approach. It is for these reasons that a shift to more sophisticated and more productive systems like man–computer graphics will be more gradual than we may prefer." However, this factor may perhaps more appropriately be seen not as a problem but a saving grace (as my colleague D. Beevis has suggested), because the delay it causes may enable hidden difficulties to be revealed and solved or to be allowed for in cost-effectiveness decisions.

4.3. *Remote Entry*

System Aspects

Under the heading of system aspects here, there seem at present to be two equally important problems needing much research: response time and language.

The question of response time has already been mentioned in Section 4.2 above. For their so-called ' instant ' batch processing, Adams and Cohen (1969) quote a range of ' from a few seconds to ten or fifteen minutes for short jobs '; commercially available time-sharing rented terminals usually provide responses within this range, and mostly, it is thought, towards the bottom end in terms of a few minutes even when the system is well loaded with users. While several research workers have pointed out the need (e.g. Carbonell *et al.* 1968), it is only recently that some results have become available from studies of the effect of response delays upon human performance. Miller (1968) found that a wait as long as fifteen seconds for a reply to a query could be nearly intolerable, and that as delays lengthened from two seconds upwards, a point was reached where the mental efficiency of the user suddenly started to drop off. They speculate that this is related to short-term memory capability. It is understood that an interesting paper on this subject is to be presented at the international symposium in Cambridge by Yntema *et al.* (1969).

The question of language is too complex to discuss here, but it is probably the biggest problem and its importance cannot be over-emphasized. For instance, Moresi (1967) considered that time-sharing was, in effect, being 'oversold', especially in relation to its actual capabilities in language. He illustrated this by quoting the failure of *COBOL*, the commercial programming language aimed at a closer approximation to English, which he considers 'extraordinarily wordy, difficult to learn and incapable of translation into efficient computer code'. He suggested that there is not enough evidence to bear out the manufacturer's claims, and that hardware technology is advancing faster than our ability to assess its worth. While many may consider that Moresi perhaps expresses an extreme view, there is no doubt that many also will agree on the need for some comprehensive evaluation studies comparing different languages. The complexity and time required for such studies must not be underestimated, but it may be suggested that the time is now over-ripe for some facts to replace the many opinions which are expressed. The controlled testing methods of the experimental psychologist are essential here, to ensure that reliable and valid results are obtained from trials with human subjects.

Similar evaluation, it is suggested, is needed to compare the time-sharing systems available on a commercial basis, which have facilitated the rapid growth of multi-access, on-line, man–computer interaction. While no direct ergonomics work has been found, O'Sullivan (1967) has described the experience at Raytheon over two years, using services from nine different systems, averaging 300 to 400 terminal hours per month. His comparison of the qualities of the different systems, statistics of system usage, and conclusions from his experience, are probably of interest and relevance to any organization considering the possible use of such a rental service.

As an example of an interesting system aspect, which is equally also an important hardware interface question, the whole subject of man to machine input procedure may be mentioned, whether it should be by keyboard or by other methods such as voice input, etc. To illustrate the type of research, results, and discussion of implications to be expected from a competent human sciences contribution in this field, the study by Root and Sadacca (1967) may be described. This involved an experiment with 20 subjects using real system messages and comparing written, teletyped and verbal transmission methods. The subjects, trained interpreters of aerial photographs, composed target reports from simulated pictures, and then either teletyped them immediately while composing (direct entry), or handwrote or voice tape-recorded them for subsequent teletyping either by themselves or by another 'communicator'. The messages had a maximum of 224 characters if in fixed field format, but otherwise their length is not stated; the subjects were all trained teletypists above a minimum speed of 35 w.p.m. The task times were similar but the errors were significantly worse when another person transcribed the messages; for simplicity the detailed data on this aspect are left out of the summary of results presented in Table 2. The figures are rounded off to 10 seconds and 0·1 error, and all are averages per image frame completed and message sent.

Table 2. Time (secs) and errors for three message entry methods

	Total time	Compose time	Transcribe time	Undetected errors
Direct entry	200	—	—	1·5
Handwrite + teletype	270	140	130	1·5
Voice tape + teletype	360	170	190	2·1

Several conclusions from this study seem justified. The direct entry method seems to be recommended where the best total speed and accuracy are needed, where there is no reason to save the message generator's time by delegating the data entry task to another, and where he could be taught typing efficiency (e.g. to more than 35 w.p.m.). Examples of this type of situation are mainly on the military field but could also be, for instance, the air traffic controller's task. However, where the message generator is a costly specialist (e.g. a hospital doctor), or where he is not and cannot be taught to be a fast typist, then his time could be saved by having a clerk to do the data entry. But in such a case, when errors might sometimes be vital (e.g. drug prescriptions in hospital), it could well be advisable for the specialist to enter certain details directly, especially since the experiment showed significantly worse errors when transcription was by another person.

Thus, it seems clear that any decision on method must depend on a detailed and thorough analysis of the data entry task and of the situation requirements; different cases may well merit different solutions. Some deductions can be made from this experiment, as a first guide for some situations. However, some caution in interpretation is needed and more research would be desirable to enable better guidance to be offered.

Hardware Interface

The need for more research in the hardware interface area is evident in a number of aspects. For instance, while the previous example suggests that direct entry via a keyboard may continue to be a useful method, it does not follow that a conventional typewriter keyboard is the best solution. Indeed, there is considerable evidence to suggest that better keyboard solutions could be developed.

Turning from input to output, an aspect of display design to which too little attention has been given is the maximum size, in terms of the number of character spaces available, if an alpha-numeric display, or the physical size and resolution, if a graphical display.

For example, typescript and book pages typically comprise 60 to 80 character spaces per line and 30 to 50 lines per display (i.e. per page), totalling about 3000 to 4000 spaces. Alpha-numeric C.R.T. displays typically comprise about 13 lines of 40 to 80 characters, i.e. 500 to 1000 spaces, and the largest is about 40 lines of 50, i.e. about 2000 spaces. Thus the user is presented with, at most, one-third to one-half of the page size with which he is familiar; does this significantly affect performance, especially if turning the page is not so easy as with a book or file? Again, sketches and drawings typically range in size from an $A4$ page up to a 50×30 in. drawing, but in all cases with a human visual capability of about 1 thousandth of an inch and a line drawing resolution of about 5 thousandths. Graphical C.R.T. displays have limited picture size and resolution so that drawings, such as circuit diagrams or architect's plans, often cannot be presented whole. Various techniques for zooming and using a movable ' enlargement window ' are being developed; but the question again arises, do these limitations significantly affect performance?

So far, we have not found any relevant evidence on these questions, and we must hope that the gap will be recognized and research stimulated. While it seems likely that engineering progress will in due course overcome these limitations, it is suggested that, at the least, ergonomics research could lead to a better understanding of how far such developments must go to satisfy essential user needs. Moreover, since better display performance is always likely to cost more, the results of such research should help the user to make a cost-effective choice between different displays for different types of usage.

As a final example of important needs for the user in this hardware interface section, several workers (Shackel 1965; Carbonell *et al.* 1968) have pointed out the lack of feedback to the user when response delays occur. Even simple warning lights, to indicate system active or in fault, and preferably a display, if possible, of some statistics on current operating characteristics such as present load and system response time, would be expected greatly to increase user acceptance and satisfaction.

Software Interface

Turning to software interface aspects, this is an area in which little work has been done in the specific context of computers, although much intuitive knowledge exists from graphic design and O. & M. work on the clarity of forms, notices, etc. A number of relevant experiments have been reviewed by Shackel and Shipley (1969). More attention is needed to this whole area.

Human Aspects

Many unanswered questions come to mind under this heading, such as methods for user training, effects of differences in learning rate, interaction of learning differences and relative verbosity of programs (especially explanations), effects of rigidity or flexibility of languages and programs for general use in relation to variability of users (e.g. scientists to business men and housewives), etc. However, the most interesting and important subject is probably the study of human planning, decision-making and problem- solving methods when man is directly coupled with a computer. Some initial studies have been made (cf. Sackman 1967; Sackman and Gold 1968), but almost everything still awaits to be discovered.

Special Usage Areas and Problems

Finally, under the heading of special usage areas, perhaps two may usefully be mentioned, The Public and Management Information Systems. As an indication of the type and size of problems which may arise when designing for truly public usage, consider Conrad's (1962) study of the success rate with a certain set of instructions for carrying out a telephone call transfer procedure with a standard G.P.O. telephone. Only 25 per cent of a large group of subjects, known to be slightly above average population intelligence, succeeded in completing the procedure correctly with the original instructions, but 75 per cent of a different but similar group were successful with a revised set of instructions (nevertheless, it should be noted that 25 per cent still did not get it right the first time). Again, but not necessarily related in terms of the human abilities etc. is the area of Management Information Systems. The report of the first year's work on a programme to study the problems of manager–computer interaction is being written (Eason and Corney 1969). It is thought that we have developed a fruitful approach to defining those manager's needs which may be assisted by a computer-based system; the skill used, and the form and quality of both the interviews and the feedback procedures developed by the psychologist, appear to be crucial factors in this process.

5. Conclusions

From the various examples and problems outlined in the preceding section, it seems clear that the whole range of the human sciences are relevant and may have significant contributions to offer in various stages. Some particular problems needing major research can be suggested for immediate attention in the near future. Of primary importance amongst these the following are suggested:

1. the development, and especially the evaluation, of programming languages;
2. the evaluation of system characteristics, particularly response time, in their effects upon human performance;
3. the ergonomics aspects of a whole range of possibilities for new communication methods at the hardware interface;
4. the software interface, which does not appear to have been specifically recognized as an area needing study;
5. the characteristics of human problem-solving in a close-coupled man–computer situation;
6. the problems involved in identifying the needs of the human user (particularly managers in management information systems, designers in computer aided design, and teachers and students in computer aided instruction), so as to ensure that the systems analysis and programming work is based upon the best studies of human needs which can be achieved.

Finally, I would like to suggest that, as well as the research needs to tackle some of the advanced problems, there is a large amount of routine work to be done which perhaps applied human scientists could help with or could do well. There has still been too little attention, even by computer designers and programmers, to the more humdrum, less romantic than ' frontiers of science ' work, on how to use better the languages and equipment available now, so as to achieve the best man–machine match and thus increase the amount of real work done. This is not in any sense to decry or minimize the challenge and importance of the research part of the field, but only to emphasize the great gap which still exists between new possible systems and their successful every day usage. Since recent surveys in the U.S.A. and Britain are said (Rowley 1969) to have found that about 70 per cent of computer installations were sub-optimum and barely cost-effective, it would seem that there is a real job of work to do, and one in which the human scientist can make a worth-while and significant contribution.

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