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Human–computer interaction – Whence and whither?

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A R T I C L E I N F O

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A B S T R A C T

In this article, an overview is presented of the growth of work in human–computer interaction (HCI) over the last 40 years. Inevitably much must be omitted, but the referenced papers may fill some of the gaps. Various formative influences and contributing disciplines are noted. Aspects of research and human factors knowledge are prominent, but attention is also given to technology, applied problems, and design for usability. Finally, after summarizing the growth in three age-group partitions, some of the major threads of development are noted under the heading of continuities from the past and perspectives into the future.

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1. Introduction

When in 1957 and 1959 at EMI in Britain (similar to RCA in the USA), I redesigned ergonomically the operating consoles for the EMIac analogue computer (Shackel, 1959a,b) and the EMIdec 2400 digital computer (Shackel, 1962), nothing could have been further from my thoughts than that I would be looking back nearly 40 years on and reviewing some of what was only starting then. While they were exciting times, only a few people at that time foresaw the growth of the whole new field now called human–computer interaction (HCI).

HCI is a major interdisciplinary conjunction of several sciences and technologies: indeed some of the evidence to be presented in this review suggests that it is fast becoming an established discipline in its own right. The first recorded papers in the literature were published nearly 40 years ago, including the prospect for "man–computer symbiosis" heralded by Licklider (1960). It is nearly 30 years since the first conference was held and the first journal was established in 1969. It is over 15 years since five major books were published in the same year, 1980, and since the microcomputer came into widespread use. Above all, the growth of research and application, as reflected in numbers of publications, conforms closely to growth curves already well-recognized in other sectors of science and technology, as indicators of maturity.

No one review can ever cover the growth of a subject over 40 years comprehensively. Unavoidably much must be omitted. And every author has his/her orientation – mine is of course British and European. But I hope that the referenced papers may fill some of the gaps: moreover, an excellent recent review, with perhaps a slightly more North-American orientation by Baecker et al. (1995) in their Chapter 1, "A Historical and Intellectual Perspective" should be read as a parallel to this article. Finally, a review of HCI technology has recently appeared on the web which will be of interest as a complement to this article (Myers, 1996).

2. Background and progenitors

2.1. Human-oriented disciplines

The disciplines from which knowledge and methods are drawn to help understand better, and thus better to design for, the human side of human–computer interaction include philosophy, physiology, medicine, psychology, and especially ergonomics (or human factors). Except for ergonomics, these disciplines were developed in the 18th or 19th centuries. Ergonomics is an applied science and technology, established this century and, from the beginning, with close ties to engineering and industry.

In Great Britain, what is now called ergonomics had its beginning in the scientific study of human problems in ordnance factories during World War I. World War II led to greater emphasis not merely on matching men to machines by selection and training, but also, much more than previously, to the designing of equipment so that its operation was within the capacities of most normal people. This fitting the job to the man increased considerably the collaboration of engineers in certain fields with the biological scientists. This collaboration, beginning primarily with military problems, continued after the war and led to the formation in 1949 in Britain of the Ergonomics Research Society.

Similar developments occurred in other countries, leading in the USA to the formation of the Human Factors Society in 1957 (now from 1994 named the Human Factors & Ergonomics Society). On the international scene, the general meeting which accepted the first constitution and rules of the International Ergonomics Association (IEA) was held during the Annual Conference of the

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Ergonomics Research Society in Oxford in 1959; the first international conference of the IEA was held in Stockholm in 1961. The IEA now has 36 member societies in nations around the world.

2.2. Computer-oriented disciplines

Among the principal disciplines from which knowledge and methods are drawn for the better understanding and design of computer systems are physics, electrical and electronic engineering, control engineering, information theory, and mathematical logic. These have led, in modem terminology, to two broad areas in the computing industry known as hardware engineering and software engineering; they also led to a third, artificial intelligence, which will not be considered in this article.

As with the human-oriented disciplines, most of the basic sciences and technologies for computing were established and developed in the 18th, 19th, and early 20th centuries, although control engineering and information theory developed through the impetus of problems of servo-mechanisms and communication systems in World War II. The applied science now known as computing, or information technology in its modern form, is usually referenced as developing first from the analytical engine of Charles Babbage in the 19th century. The potential of the modem electronic computer was first recognized in the form of analogue machines and digital systems before and during World War II.

Some of the persons whose work was particularly relevant are: Vannevar Bush (USA. MIT differential analyzer, 1930); Konrad Zuse (Germany, Z1–Z4, 1938–1944), and Howard Aiken (USA, Harvard Mark 1, 1943) – whose machines were based on electromagnetic relays. The first modem form of electronic digital computer using electronic valves (tubes) was the Colossus (1943, followed by nine others), built in Britain for cypher analysis and code-breaking during World War II and, therefore, kept secret for more than 30 years thereafter. So, the publicly recognized first electronic digital computer is the ENIAC (Philadelphia, USA, 1946), followed by the Manchester Mark I (UK, 1948, the first to incorporate a changeable stored program), the EDSAC (Cambridge, UK, 1949), and the EDVAC (USA, 1951). This and much of the early history is fascinatingly described by Evans (1981).

Scientific and engineering aspects of computing were first debated in the engineering institutions. However, the application of computers in commercial offices led quickly to the formation of specific computing and information processing societies. For example, in Britain, the British Computer Society began in 1957, while in the USA the first was the Association for Computing Machinery established in 1946. On the international scene, the first International Conference on Information Processing was held, in Paris, in June 1959 under the sponsorship of UNESCO. The need for an international body was agreed and the International Federation for Information Processing (IFIP) was formed in January, 1960, again under UNESCO auspices. IFIP is a federation of national societies only, and in January, 1996 had a membership of 55 organizations representing 61 countries.

3. Changes in computing and the growth of HCI problems

Although the domains of computing and HCI have grown rapidly, especially in the last 15 years, there have been few surveys of this joint development. With regard to computing and information technology, Evans (1979, 1981) and Forester (1985, 1987) have published excellent reviews of developments and applications. With regard to HCI, the most useful reviews are those presented by Gaines (1985) (in a Keynote Address to INTERACT'84, the First International Conference on HCI) and by Gaines and Shaw (1986a, 1986b) for the earlier growth, and the excellent Chapter 1 in Baecker et al. (1995), especially for more recent progress.

There have been changes in computing which have fundamentally altered the predominant type of users and their expectations so that the user population is no longer homogeneous. At the beginning of the digital computer era, the designers of computers were specialists and the users of computers had to become computer specialists. The power and speed of this new machine was so useful that some scientists found it worth the cost of time and effort to learn how to use it. In the late 1950s, the potential in industry and commerce was recognized, and the first business machines were developed; again, they were designed by computer specialists for use by data processing professionals.

From the mid-1960s, the mini-computer and remote terminal access to the time-sharing mainframe brought computer usage nearer to the layman. However, already the difficulties for the non-specialist and the problems of human–computer interaction were recognized (Nickerson, 1969; Shackel, 1969; Sackman, 1970). The advent of the microcomputer in 1978, in widespread use from 1980, and of the smaller portable machines from about 1990, caused much growth in the use of computers for many different purposes by non-specialists of all types – from bank clerk to business executive, from librarian to life insurance salesman, and from secretary to stockbroker and space traveler. This rapid growth in computing, leading to widespread usability problems especially from 1980, is summarized in Fig. 1.

The result of this rapid growth is that both the market for the Information Technology (IT) industry and the users of IT equipment have changed significantly. The market has become much more selective, partly through experiences of poor usability. The users are no longer mainly computer professionals, but are mostly discretionary users (as first noted by Bennett, 1979). The new users are such people as managers, physicians, lawyers, librarians, and scientists who are committed to their tasks and will only use computers if they are appropriate, useful, and usable. So, to succeed, the IT industry must improve the usability of interactive systems; designing must start with the end-users and be user-centred around them. Therefore, the human factors aspects become paramount.

Having noted the growth of digital computing and of user issues, we shall now consider the growth of attention to the human aspects of human–computer interaction. The review is divided into the three parts (1950–1970. 1970–1985, 1980–1995) which naturally occur. A synopsis of some of the main events is presented by date order in Fig. 2.

4. Beginnings of HCI (1950–1970)

Attention to the human factors and usability aspects was slow to develop, although some work primarily on military systems was being done by the late 1950s, and some on the ergonomic design of commercial computers by 1960 (Shackel, 1959a, 1962). Gaines (1985) says "Shackel's (1959a) paper on the ergonomics of a computer console is an isolate. Ten years later, in surveying work on man–computer interaction, Nickerson (1969) remarks on its paucity." Most important, the vision for the future of close-coupled symbiosis, which is still some way from being realized today in the mid-1990s, was proposed by Licklider (1960).

Through the 1960s such work as existed was scattered and mostly still related to military systems. Attention was mainly focused upon hardware issues, large systems, and process control, rather than on office and business systems. Both the mini-computer and the first time-shared, multi-access systems (MAC at MIT, and JOSS at RAND; cf. Fano, 1965 and Sham, 1968) became available from the early 1960s; these were the first to provide di-

Computer type	Approx growth era	Main users	User issues
Research machines	1950s	Mathematicians, scientists	Machine reliability; users must learn to do the programming
Mainframes	1960s & 1970s	Data-processing professionals supplying a service	Users of the output (business managers) grow disenchanted with delays, costs, lack of flexibility
Minicomputers	1970s	Engineering and other non-computer professionals	Users must still do much programming; usability becomes a problem
Microcomputers	1980s	Almost anyone	Therefore usability is the major problem
Laptops, Notebooks, PDAs	1990s	Anyone and often in mobile situations	Complexity in trying to achieve usability, especially with new input/output modalities

Fig. 1. Growth of digital computers and user issues.

Date	Event
1959	• 1st recorded paper in the literature (Shackel, 1959a, as reported by Gaines, 1985)
1960	• Seminal paper by Licklider (1960) on "Man-Computer Symbiosis"
1969	• 1st major conference ("International Symposium on Man-Machine Systems") • *International Journal of Man-Machine Studies* started • First four ARPANET nodes begin operation – leading later to computer conferencing, electronic mail and electronic journals
1970	• Foundation of Xerox Palo Alto Research Centre (PARC) • Foundation of HUSAT Research Centre (now Institute), Loughborough University
1970-73	• Four seminal books published (Sackman, Weinberg, Winograd, Martin)
1976	• NATO Advanced Study Institute on "Man-Computer Interaction"
1980	• Conference and book on "Ergonomics Aspects of Visual Display Terminals" (Grandjean & Vigliani, 1980). • Four other major books (Cakir, et al, Damodaran, et al, Shneiderman, Smith & Green)
1982	• Journal *Behaviour and Information Technology* started
1982-1984	• Seven major conferences held in USA, UK and Europe with attendances ranging from 180 to over 1000 with an average of nearly 500
1983	• European ESPRIT and British Alvey programmes begin • Major book "The Psychology of Human-Computer Interaction" (Card, et al)
1984	• First International Conference on HCI – IFIP INTERACT'84 (London)
1985	• Journal *Human-Computer Interaction* started • From 1985, the conferences of national societies ACM and BCS, on CHI and HCI respectively, become annual
1986	• Three HCI Centres launched in the UK under the Alvey initiative • Major book 'User Centered System Design' (ed. Norman & Draper)
1987	• Second IFIP INTERACT International Conference on HCI (Stuttgart)
1988	• Major handbook on HCI published (ed. M. Helander)
1989	• IFIP establishes Technical Committee on HCI (IFIP TC 13) • Journal *Interacting with Computers* started • *International Journal of Human-Computer Interaction* started
1990	• Attendance at ACM CHI Conference reaches 2,300 • Third IFIP INTERACT International Conference on HCI (Cambridge) • CEC (1990) Directive promulgated on Work with Display Screen Equipment
1992	• Attendance at ACM CHI Conference reaches 2,600
1993	• CEC Directive on Display Screen Equipment comes into operation • Fourth IFIP INTERACT International Conference on HCI combined with annual CHI Conference in Amsterdam to make INTERCHI'93 – over 1,500 attendance
1994	• Journal *ACM Transactions on Computer-Human Interaction* started
1995	• Fifth IFIP INTERACT International Conference on HCI (Lillehammer) • ARPANET has grown, changed and been acclaimed The INTERNET, setting new HCI problems

Fig. 2. Growth of attention to ergonomic/human factors aspects of human–computer interaction.

rect "hands-on"' access to computing power for the non-computer professional, and thus stimulated interest in the ergonomic issues because of the problems found by these non-specialist users.

Early foundations with far-reaching consequences were laid at this time by several other groups. Among these perhaps the most significant were those led by Engelbart, by Nelson, and by Sutherland. At the Stanford Research Institute, Engelbart built a group to develop the concept of augmenting human intellect via advanced computer tools; they foresaw the importance of close coupling the human, and, in 1966, I saw the workplaces fitted around the users with the (first) mouse and a 5-key keypad alongside a standard keyboard together with two screen displays for some. Already they were involved in computer-supported cooperative work, and they effectively invented WYSIWYG word-processing, multi-window display, and electronic meeting rooms (Engelbart, 1963; Engelbart and English, 1968).

Nelson also recognized the importance of the quality of the interface to the user, but his focus was upon the way in which the computer could, if new structural concepts were facilitated, enable an escape from the hitherto immutable linear presentation of text.

> Let me introduce the word *hypertext* to mean a body of written or pictorial material interconnected in such a way that it could not conveniently be presented or reproduced on paper. It may contain summaries, or maps, of its contents and their interrelations; it may contain annotations, additions and footnotes from scholars who have examined it. Let me suggest that such an object and system, properly designed and administered, could have great potential for education, increasing the student's range of choice, his sense of freedom, his motivation, and his intellectual grasp (Nelson, 1965).

Thirty years later hypertext is no longer a hypothesis!

Equally innovative was Sutherland's (1963) Sketchpad system, by far the most important progenitor of computer graphics, He devised and demonstrated such major facilities as zooming the window in and out, rubber-band drawing, grasping parts or wholes as objects which can then be resized, rotated, dragged, etc. (i.e., direct manipulation); also, any drawing could be used as a master altered, copied, combined with an earlier version to form compound objects, and so on. Many of' his innovations had to wait for some time until powerful enough computers could enable others to enjoy them.

The end of the decade was marked by the first international meeting, which was held in 1969 in Cambridge, UK (International Symposium on Man-Machine Systems), and also by the establishment of the first journal for the area in the same year *(International Journal of Man-Machine Studies – IJMMS).* As Gaines (1985) said

> The landmark year was 1969; Ergonomics had a special issue based on papers to be given at an International Symposium on Man–Machine Systems; the IEEE Transactions on Man–Machine Systems reprinted the same papers to give them wider circulation; IJMMS commenced publication. As editor of IJMMS I can attest to the difficulty of obtaining true human factors material for publication in those days. As a scientific discipline the field did not yet exist, but what we could pass on was a wide variety of user experience of interaction systems applied to many tasks (p. 3).

5. Foundations of HCI (1970-1985)

The early part of the 1970s saw the laying of foundations which led to the major development of the field from 1980 onwards. The decade began with the publication of four important books which stimulated much work by indicating the wide range of problems to be addressed. These were by Sackman (1970), based on extensive empirical studies of problem solving with the aid of computers; by Weinberg (1971) mapping the range of psychological issues to be addressed to better understand and improve the quality of computer programming; by Winograd (1972), indicating the scope of the problems when aiming to program machines to respond to human natural language, and by Martin (1973), providing advice from practical experience to aid the design of better man–computer dialogues with mainframe machines.

One of the other landmark events in 1970 was the establishment of two centers which have grown considerably, each in their own way, to make considerable contributions to the field of HCI. Because of my personal involvement with one, it is more appropriate to quote part of four paragraphs excerpted from the review in a small but comprehensive bibliography on *Computers: The Non-Technological (Human) Factors* by Burch (1984).

> ***The first sustained research on computer usability: HUSAT and PARC***
>
> Real progress in developing a science of computer usability did not begin until around 1970. Two research groups. HUSAT and PARC, both founded in the landmark year of 1970, have had a strong and continuing influence on the growth and structure of the field. Each brought a new approach to computer ergonomics and has contributed new insight and findings, not just new buzzwords (p. 10).
>
> The HUSAT Group, while not exclusively interested in computer-related issues, has nevertheless played a leading role in applying the concerns, methods, and knowledge traditional to the field of' ergonomics to the study of computer design and use. They have built extensively upon that foundation. Their work has covered a broad spectrum of problems and subjects, ranging from keyboard ergonomics to the dynamics of organisational change. Today, HUSAT-trained researchers and practitioners are active in the field throughout the world.
>
> It was also in 1970 that the Xerox Corporation created its now famous Palo Alto Research Center (PARC). PARC's mission was to provide research support for Xerox's entry into the business of digital office technologies and systems. PARC quickly established a focus on human factors issues and was able to build on the previous work of Douglas Engelbart at Stanford University and his concept of a "knowledge augmentation workshop." Artificial intelligence has also been a fundamental part of the work at PARC. Research there eventually led to the design of the well-known Xerox product, the STAR workstation, and its subsequent look-alike from Apple Computer, the LISA computer (and today's MACINTOSH – *BS*) (p. 10).
>
> HUSAT and PARC began scientific research on the problem of computer usability before most others had even begun talking about it. (p. 11).

Through the 1970s, much other significant work was also developing, though still largely in small, somewhat isolated groups. Most of this work was brought together and reported at the first specialized international workshop to be held: this was in 1976 in the form of a NATO Advanced Study Institute on man–computer interaction with edited proceedings (Shackel, 1981). The growing attention to ergonomics and usability issues was considerably stimulated by the arrival of the micro-computer in 1978, which came into widespread use from 1980. Thereafter, there was rapid growth in work on the human factors of computer systems for office, business, and commercial use.

The 1970s ended with the publication of a draft standard in Germany embodying the user-oriented approach to the design of visual display terminals, which had been developing in Europe with Sweden at the forefront. Among other items, the draft ergonomic German DIN standard specified keyboard height to be not more than 30 mm. This draft standard caused many organizations in Germany and elsewhere in Europe suddenly to refuse to purchase terminals designed to the US practice current at that time.

The recognition that an ergonomic standard could override all other considerations in the marketplace came as a big surprise and had a powerful effect on quite a number of US companies. Probably as a result there was a rapid increase, averaging 300% from 1980 to 1983, in the number of human factors professionals employed in parts of the US computer industry (from a small survey of 15 large companies in 1984: Shackel, 1987).

The 1980s began with five books in one year which crystallized the recent considerable growth in more focused work upon specific issues. Smith and Green (1980) showed the scope of focused research and Shneiderman (1980) showed some of the contributions from psychology to computing which carried added conviction by coming from a computer professional. Cakir, Hart and Stewart (1980) and Damodaran, Simpson and Wilson (1980) presented the first ergonomics guidebooks for HCI usable equally by computer designers and human factors consultants. The last (Grandjean and Vigliani, 1980) contains articles from the first conference on visual display terminal ergonomics which reflected growing concern about some aspects, including possible health hazards which were explored in the 1980/1981 series of three meetings held in Britain (Pearce, 1984).

Perhaps the most important foundation to be laid was the first major attempt to formulate some theoretical bases for the field of HCI. This was done by Card, Moran, and Newell in their outstanding text (1983). Based upon current psychological knowledge about human performance and its descriptive theories, Card et al. proposed a model in information processing terms to describe human performance when interacting with computers and called it the Model Human Processor (MHP). From this theoretical approach and extensive data on human performance in various basic actions, they then proposed specific operational models by which to analyze human-computer task activities and to predict total task performance times as the sum of the individual unitary activities – so-called GOMS models (Goals, Operators, Methods, and Selection rules) and Keystroke Level models. In several thoroughly worked examples, they showed the value and promise of this approach and also its limitations. As with all good theoretical approaches, their stimulus fuels a wide range of studies today and into the future.

6. Development of HCI (1980–1995)

We now move from foundations to development: to some extent these two phases of course overlap – hence the overlap in the range of dates. The focus of HCI as it developed towards maturity is best indicated by the title of a second major book from the middle of the 1980s, *User Centred* System *Design* (Norman and Draper, 1986).

In no way do I mean that everything changed from theory and research to application and practice. There was and still is much not known and therefore unable to be applied, but Norman and Draper emphasize a *coordinated approach* to the design of computers from the user's point of view. Further, by 1988, enough had been done in this growing field to justify an ample handbook (Helander, 1988).

The increasing attention to HCI is shown by the growth during the 1980s in the number of journals and books and in papers offered to conferences and published in journals.

6.1. Growth in journals, books, and society groups

The *International Journal of Man–Machine Studies* has been published since 1970. But in 1981 it doubled its production to consist of two volumes a year with issues published monthly. A new journal, *Behaviour and Information Technology,* was established in 1982 and grew successfully with quarterly publication and an average of sixarticles per number. Further journals – *Human–Computer Interaction, Interacting with Computers*, and *ACM Transactions on Computer–Human Interaction* were started in 1985, 1989, and 1994, respectively.

Again, books and conference proceedings show similar growth. As part of a survey, Shackel (1985a) listed and plotted the growth in the number of relevant books published annually over a period of 14 years. This showed a marked increase from 1980–1983, with five published in 1980 and 14 in 1983.

Another sign of growth is the appearance of interest groups and scientific societies. Through the 1980s, national groups developed in a number of countries. For example: In the USA the Computer–Human Interaction Special Interest Group of the Association for Computing Machinery (ACM SIGCHI) (recently the fastest growing ACM SIG with already over 6000 members); the HCI Specialist Group of the British Computer Society (BCSHCI SG); the Fachausschuss Software Ergonomie of the Gesellschaft fuer Informatik (GI FSE); the joint Man–Machine Interaction group of the Dutch Computer and Dutch Ergonomics Societies (NGI and NVvE MMI) ; and the Computer Human Interaction SIG of the Australian Ergonomics Society (CHISIG OZ). These groups have gradually developed regular meetings; the ACM and BCS (CHI and HCI) conferences became annual from 1985, and their proceedings provide not only a record of current work but also a valuable archive of empirical results.

6.2. Growth of papers at conferences and in the HILITES database

Perhaps the best evidence of HCI growth from 1980 is the growth in papers presented at conferences and published in journals. For example, at the 1981 Human Factors Society conference there were 32 HCI papers, while at the 1983 conference there were 71 (more than double, although the total of papers increased by under 50%). Again, about 130 papers were offered for consideration and 58 were presented at the ACM CHI'83 conference, and 282 papers were offered for consideration and 153 were presented at INTERACT'84 in London. The growth is even more evident from the four INTERACT conferences about which I have data; for INTERACT'84, '87, '90, and '93, respectively, the number of papers submitted increased from 180 to 231, to 312, to over 400. Each time the increase is of the order of 30–35%.

Perhaps the most cogent evidence comes from an analysis of the documents stored in the HILITES database (the Hci Information & LITerature Enquiry Service at Loughborough University, Shackel et al., 1992). A listing was made of the total number of documents with a specified year of publication. This listing is presented as a table in Fig. 3. The same data are plotted in Fig. 4 which shows the exponential growth curve (the discrepancy for 1985 is presumed due to a backlog during the startup year).

These data plotted in Fig. 4 should be compared with physics abstracts growth from 1900, in Fig. 5, as presented by de Solla Price (1963) showing results of his studies of the growth of published

Documents by Source Year

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Docs	11	31	37	81	119	173	338	583	530	1638	2550	4561	5203	5499

Fig. 3. Table of documents by source year in the HILITES database.

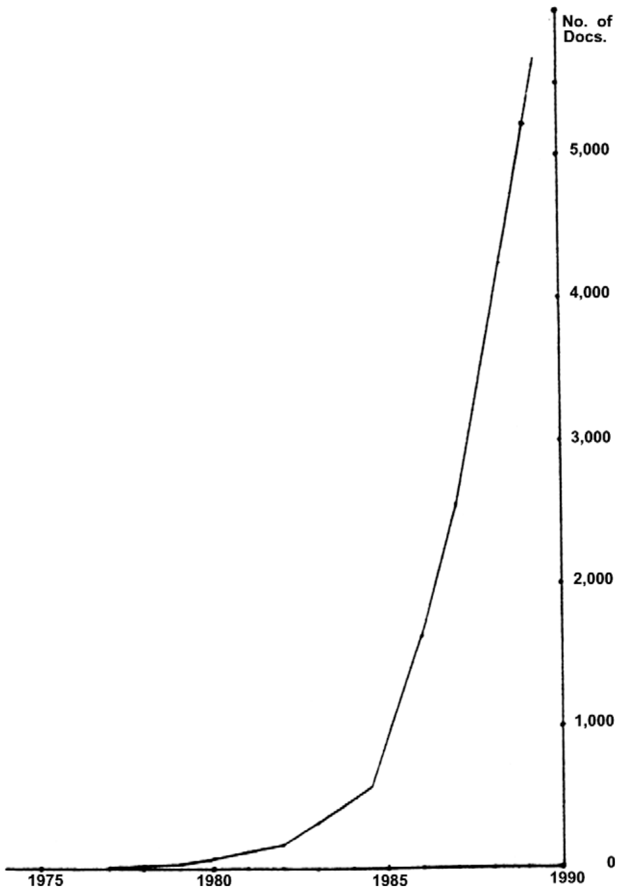

Fig. 4. Plot of growth of' documents in the HILITES database.

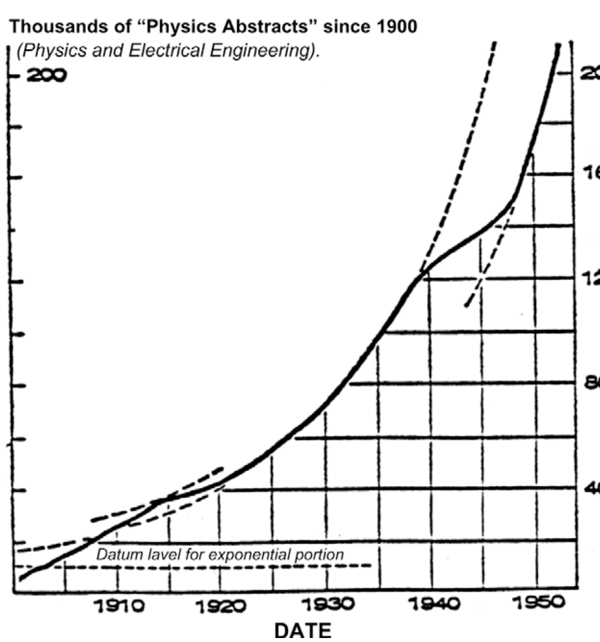

Fig. 5. Total number of physics abstracts published since January 1, 1900. From *Little Science, Big Science* by Derek De Solla Price. Copyright (c) 1963 by Columbia University Press. Reprinted with permission of the publisher.

output in various scientific disciplines. A logarithmic plot of the HILITES data can also be compared with a similar plot from Price (1963) of the growth of abstracts in various scientific fields (Chemical, Biological, and Physics Abstracts). The growth in HCI conforms closely to the exponential patterns presented by Price, who shows how this pattern appears to be characteristic in the growth of many scientific disciplines. Thus we see typical patterns to suggest the growing maturity of HCI.

6.3. The stimulus of funding programs

There is no doubt that much of this growth in HCI was stimulated and partly financed by the funding programs of the 1980s.

The rapid growth of IT since 1982 was driven by the major funding programs in Japan, Britain, and Europe. These programs did give more support to human issues than any hitherto. For example, the Japanese Fifth Generation Conference Report (Moto-Oka, 1982) stated that the intention of the new program was to gain knowledge needed to develop systems in which "intelligence will be greatly improved to match that of a human being, and, when compared with conventional systems, the man-machine interface will become closer to the human system" (p. 7). Similarly, the report of the Alvey Committee in Britain (Alvey, 1982) stated: "Information technology helps man handle and use information, and the system designer's aim is to produce a machine that matches, complements, and extends man's capability" (p. 21). So one of the four areas supported by the Alvey program was the Man–Machine Interface with over £10 million allocated to broadly HCI topics.

At the same time as the Japanese and British programs, an even larger initiative started within the European Community under ESPRIT (European Strategic Programme for Research in Information Technology) with pilot projects in 1983. The progress of ESPRIT was recorded in successive annual conference proceedings (ESPRIT'84 to ESPRIT'94) published by North-Holland. The first ESPRIT program was succeeded by others, also involving human factors to some extent. The European Union funding grown, now into the Fourth FRAMEWORK Programme (1994–1998), and the proportion allocated to usability (by name) and to human factors has likewise increased.

In the USA, there was nothing equivalent in direct government funding. Although the US computer industry was of course concerned that the programs in Japan and Europe (approved simply to try to reduce the large US lead) would erode its supremacy, only indirect funding was available from Congress. Several major US computer corporations funded a consortium called MCC (Microelectronics and Computer Technology Corporation) located in Austin, Texas. This did good pre-competitive research in HCI also under the leadership of Bill Curtis (as MCC was running down he moved to Carnegie–Mellon University where now the cognitive modeling research continues the thrust started by the Card et al., 1983 theory initiative).

7. Continuities from the past and perspectives into the future

In this section, I aim to illustrate several continuities in the development of computing and HCI, to discuss related issues, and to indicate some perspectives into the future.

7.1. From system supremacy to personal empowerment

In the beginning, the computer was so costly that it had to be kept gainfully occupied for every second; people were almost slaves to feed it. With multi-access time-sharing, the economics were improved and above all users began to feel the potential of direct control. At Xerox PARC in the mid-1970s, the Alto, a prototype "workstation", was produced; eventually many were linked via a network to give the first example of today's powerful Local

Area Network (LAN) of personal computers (Thacker, 1986). At the same time, in rapid succession from 1975 to 1984, the personal computer was developed, from the Altair kit to the Apple II and Commodore PET, the IBM PC, the Apple LISA and MACINTOSH (see Goldberg, 1988, for the history). The continuity of steady development to today's personal and desktop machines is obvious from 1984.

Likewise, from the early days, portability with power has been a goal. Kay and Goldberg (1977) first proposed a clear specification, which they called the Dynabook. Towards this goal, the industry has striven to capture new markets with laptops, notebooks, and now Personal Dynamic Assistants (PDAs). The power under the user's control today is amazing – I am writing this on a small laptop (280×160 cm) with a processor over 1200 times more powerful in size and speed, and with deep store several times larger and more quickly accessed, than the EMIdec2400 for which I redesigned the operating console in 1959 (Shackel, 1962) that was the largest all transistor computer in the world then and occupied a room at least 15×15 m.

But the tendency in recent years has been for the industry to go for new gimmicks to try to boost sales, such as handwriting and voice recognition, before performance is satisfactory instead of improving on obvious HCI limitations. For example, from early days (cf. Licklider and Clark, 1962) the need for larger displays has been emphasized; but just when it seemed, in the late 1980s, that full page and larger displays would come with lower prices, the focus in the industry switched to portability and we moved backward at first to smaller screens. While there are signs of improvement (see below) larger screens are still not available at an acceptable price. Similarly, in their Dynabook concept, Kay and Goldberg (1977) specified a display the size of a full paper page; I am not aware of any portable laptop, let alone notebook, etc., which has a page size screen.

This basic HCI need – an electronic input–output surface for correlated symbolic and pictorial information (as stated by Licklider and Clark, 1962) – is being studied. Although one solution (the LiveBoard or electronic whiteboard: Elrod et al., 1992; Moran et al., 1995; Pedersen et al., 1993) is already available, it has been envisaged as a device to support group work rather than as the input/output medium in a work-place for single users similar to the way we gather things around us on our desktop. Newman and Wellner (1992) did some initial work for the individual desk; Stafford-Fraser (1996) have just shown a simpler compact unit for whiteboard scanning and command input; but only for computer-aided designers are there systems which approach the concept of the complete "computer augmented" workstation. Above all, at present such devices are far too expensive.

But for real empowerment, surely the personal workstation must enable many different information sources to be displayed simultaneously on a large array and manipulated easily by the user? In fact, apart from details of the underlying technology, the HCI workplace needs to be very much as Bush (1945) (so often quoted but little copied) actually envisaged, and as Weiser (1991) suggested in a speculative description of "ubiquitous computing."

7.2. From multi-access to the Internet

Multi-access first enabled individual usage that led to new applications such as text-processing, full-screen editors, and eventually word-processing (Meyrowitz and Van Dam, 1982). These tools were, until the early 1980s, on central mainframes able to support 1000 or more remote users who could easily send messages locally and soon wanted wider linkage (Licklider et al., 1968). Funded by the US DoD Advanced Research Projects Agency (ARPA), the first four nodes of ARPAnet started in 1969 (Roberts, 1986). Steady growth and academic research led to new facilities for electronic mail and computer conferencing (cf. Vallee, 1972; Hiltz and Turoff, 1978; Johansen et al., 1979) and also led to the electronic journal which will be discussed in the next section.

Gradually what started with defence funds was developed technically into a research communication network for electronic mail and then as a vehicle for widespread information search and retrieval. Use blossomed with recognition of its importance to aid national research and to support business and community activities; parallel progress in CSCW and hypertext (see later Section 7.4) gave interlinking stimulation in the early 1990s. The international potential was recognized, and the Internet "takeoff" began. Strictly, the "Internet" is the underlying communication framework rather than the services and content, but already it has been adopted as a convenient general name; a useful summary of the concept, structure, content, and growth of the World-Wide Web (WWW) is given by some of the progenitors at CERN (Berners-Lee et al., 1994). They also outline some of the future possibilities as follows.

> Apart from being a place of communication and learning, and a new market place, the Web is a show ground for new developments in information technology. Some of the developments that we look forward to in the next few years include:

- ○ The implementation of name servers that will allow documents to be referenced by name, independent of their location.
- ○ Hypertext editors allowing non-expert users to make hypertext links to organize published information.
- ○ The development of a common format for hypertext links from two and three dimensional images giving exciting interface possibilities.
- ○ . . .
- ○ Conventions on the Internet for charging and commercial use to allow direct access to for profit services (p. 81).

These (and others omitted here) are all sound user needs and are being worked on. But there are other more basic HCI needs to be addressed if use of the Internet is to become as universal as may be hoped, including:

- ○ Implementation of name servers that will allow people to be located via some simple process instead of the current complicated web addresses, or appropriate directory systems to enable the same.
- ○ Radically simpler methods (which better match their expertise and tasks) by which non-expert users can find, store, and retrieve the everyday information they will wish to call up and use (cf. one approach to part of this problem by Card et al., 1996).
- ○ The wealth of information now available to be retrieved, reviewed, and worked upon still comes, for most people, through this small window less than one standard page in size (as noted above). To integrate the Internet into regular work patterns needs a large "computer-augmented" workplace to empower single users (as discussed above).

One of the next stages of Internet development is to support electronic communities (cf. the well-known work on "invisible colleges" by Crane, 1972). The HCI aspects of these are already being explored. For example, in a tutorial on network communities, Carroll et al. (1996) took participants on a visit to the Blacksburg Electronic Village (BEV, 1995); they described the mechanisms of and applications in network communities, such as education (Hiltz, 1993) and business (Nunamaker et al., 1991), and illustrated how.

Many technical groups are now making significant use of networks to carry out routine science and technology work; BioMOO (1995) is an example in which high resolution graphics are made available via Web pages that are viewed in conjunction with MOO discussions (via telnet). Several science and technology applications are directed at understanding the World-Wide Web (WWW) itself; Web Interactive Talk (WIT, 1995) is an asynchronous Web conferencing application for brainstorming uses for the Web (p. 358).

These growths on the Internet relate closely to our next two topics.

7.3. From augmentation to electronic journals

As noted earlier, Engelbart and Nelson were the prime initiators whose work led to the fields discussed in this and the next section. Special programs were developed through the 1970s to support structured communication via logging into remote mainframes, soon named computer conferencing; the two best systems (EIES and NOTEPAD) were used for a wide range of exploratory, studies (cf. Hiltz and Turoff, 1978 and Johansen et al., 1979) of what is now called CSCW (cf. Baecker et al., 1995, Chapter 11, pp. 741–753). They were also used by other researchers for the first attempts to develop electronic journals (in the sense of the traditional scientific publication).

The first study was in North America (1978–1980) but for a combination of reasons "fell short of its aims (Sheridan et al., 1981); however, lessons were learned (Senders, 1984). The BLEND Project in Britain (1980–1985, Shackel, 1982) successfully archived articles in four types of journal (18 refereed articles in four numbers of a traditional journal, 22 unrefereed articles in a poster journal, 17 reviews in a software reviews journal, and over 1100 references and abstracts in a bibliographic journal (Pullinger, 1990: Pullinger and Howey, 1984: Shackel, 1986, 1991). The results also showed why electronic journals could not be expected to succeed yet, including 11 improvements for all electronic formats to meet basically human factors needs (Shackel, 1989; Shackel et al., 1985) (see Fig. 6).

During the follow-up Project Quartet (Tuck et al., 1990), also funded by the British Library, McKnight et al. (1991) designed and built the world's first hypertext electronic journal HyperBIT. The articles in the first eight volumes of *Behaviour & Information Technology* were structured using the GUIDE hypertext system; when reading a paper one could instantly, via the hypertext links, see in a pop-up window (without obscuring the exact text being read) a table, or a figure, or the full reference of a referenced item, and then, if it was an article in BIT, click again to jump to that article, etc. For the first time in my experience, the electronic version had several advantages over the paper version.

As some of the needed improvements came, more electronic journal projects were launched: For example ADONIS (Campbell and Stern, 1987), CORE (Landauer et al., 1993), TULIP (Zijlstra, 1994), CAJUN – two journals published in parallel in print and on CD–ROM under Adobe Acrobat (Smith et al., 1993), and ELVYN – delivering a new start-up journal electronically via the Internet directly, to seven libraries for immediate user access via campus networks (Rowland et al., 1995). These and several other recent electronic publishing activities are described more fully in Chapter 2 of Rowland et al. (1995).

Since 1993, the World-Wide Web has stimulated much activity, as is evident from the following data taken from the 1991, 1993, and 1995 (on-line) editions of the Directory of Electronic Journals, etc. (cf. Okerson, 1995) in Fig. 7.

However, many of the 675 "journals" in 1995 are estimated to be unrefereed newsletters (Woodward in Chapter 4 of Rowland et al., 1995). The performance of the Mosaic and now the Netscape web browsers, above all with much improved graphic capabilities, seductively suggests spurious syllogisms such as: journals are good things and the Web is easy, speedy, and graphical so web journals will be easy and good – and many seem to have fallen into this trap. (I personally have responded or subscribed to several proposals which have fizzled to naught; also 16 of the 27 in the 1991 Directory were no longer in the 45 listed in 1993, and of those 45, a further 13 are no longer in the on-line 1995 version). But some have undoubtedly been successful (e.g., *HUMBUL* started by Meadows pre-WWW, cf. Katzen, 1988; *Psycholoquy, 1996*, cf. Harnad, 1995, to mention just two).

From over 15 years of hopes, expectations, and many enthusiastic attempts, it is evident that to establish a successful electronic

To improve acceptability to users of all electronic formats:

- 1 or 2 x A4 page display with black on white presentation and screen refresh rate 72 - 90 hz
- Better facilities as appropriate -- graphics, color, sound, gesture
- Better manipulation facilities
- Better structures matched to users' needs, e.g., "Information Lens." Hypertext
- One-to-many is very easy so aids to filtering, e.g. remove "junk mail"
- Matching users' models to help the transition from paper to computer
- Standardized formats and protocols for universal interchange
- Ready access, i.e. on user's desk -- therefore price cannot be ignored
- Faster communications speeds
- Integrated system -- one workstation supports E-mail/conferencing/journals/database search and printing for offline reading
- Internationally agreed and integrated networks, procedures, and charging

Fig. 6. Improvements needed to the electronic medium (from BLEND results: Shackel et al., 1985; Shackel, 1989).

Reported growth in:	1991	1993	1995
Electronic journals	27	45	100
Electronic newsletters	67	195	575
Academic discussion lists	500+	1,152	*

Fig. 7. Growth in electronic media (*discussion lists are not in the 1995 on-line version).

journal is not at all easy; to some extent the technology has still not been developed enough, or if developed is not yet cheap enough, to meet all the improvements suggested from BLEND to achieve acceptability (Fig. 6). Nevertheless, it is clear that the major needs to be satisfied are still human factors; McKnight (1995a) brings together in one table many of the key guidelines for electronic journal design.

So what are the prospects into the future? Despite the stimulus from the Web, the most likely progress is still gradual rather than dramatic. It will still take time for the human factors needs summarized in Fig. 6 and McKnight (1995b) to be met by technology improvements down to an acceptable price. Above all there remain some very basic unresolved issues from BLEND till now. The two most significant are the question of a basic unit (or what is an electronic journal page?) and how many reading/handling systems will users have to learn?

Regarding the first, if the CAJUN approach, for example, is not followed and no conformity is maintained between the original "published" or archived page and the text read by the user on his/her screen, then is the basic unit a paragraph or what, and how does one refer easily to any item in an article? Regarding the second, the Project ELVYN report (Rowland et al., 1995) ends its final paragraph.

> One major worry for both (*publishers and librarians – but equally readers BS*) concerns the need to standardize the handling of electronic journals. For libraries to try to establish different handling systems for different titles would he both expensive and an organizational nightmare. Correspondingly, publishers who insisted on tackling things in their own individualistic way would soon encounter resistance. It remains to be seen whether *de facto* standards will prove sufficient (p. 158).

7.4. And to CSCW, hypertext, and digital libraries

The focus upon HCI in electronic journals has been given more space because there are no recent overviews readily available on this topic. Moreover, I suggest that some of the electronic journal progress and issues are relevant in the wider CSCW context. My other reason is that, because such an excellent recent review of CSCW exists, I need not waste space repeating what has been better written already. Therefore, may I urge you to read Chapter 11, pp. 741–753, on Groupware and Computer Supported Cooperative Work in Baecker et al. (1995). With regard to HCI issues, upon which many groupware ventures have foundered, one cannot do better than read Grudin (1988) on why failures occur, and Grudin (1994) on challenges for designers with excellent advice on facing them.

On *hypertext*, I have the same position as for CSCW but also I have some balloons to prick. Again, the 1995 Readings has a good overview, so rather than write a poor substitute may I urge you to read Chapter 13, pp. 833–842, on Hypertext and Multimedia in Baecker et al. (1995); but always read with eclectic scepticism. In 1987, a special issue of *IEEE Computer* was published in the USA on hypertext, with the fine review by Conklin (1987), and the HyperCard software was bundled with each new Apple Macintosh computer. Enthused by the charismatic visions of Ted Nelson (coiner of "hypertext"), everyone could become their own Nelsonian ruler of Xanadu, and hypertext was seen as the solution to all problems. But as Chapter 13 (Baecker et al., 1995) says of the other good review, by Nielsen (1990), "the predictions in this book were later revised for a 1993 paperback edition, since events had not gone as expected (Nielsen, personal communication)" (p. 837).

Salutary advice for designers was given by Glushko (1992), and careful thought about the users' tasks to be supported should lead to sound decisions about what hypertext tool capabilities would be useful and usable in each circumstance. As a scientist originally brought up in the classics, I have always wondered at the excessive enthusiasm by some for hypertext. With encyclopedias and maintenance/repair manuals, where the basic unit of information is a discrete entry (with possible cross-references), and the organizing principle is readily seen (often alphabetical order by topic), the value is obvious. But why removing structure from scientific papers, essays, novels, or detective stories should be thought to be advantageous puzzles me and seems to be a facile faulty deduction from the observation that *some* people, but by no means all, skip around when "reading" a scientific paper or even like to read the end of a detective story first! What is so easily overlooked is that there must already be a consistent and recognizable structure for the reader to be able to jump around with confidence.

However, I think I understand the initial enthusiasm for hypertext as an aid to writing; most prepare by making many short notes which later are much reordered and then developed further into the final text – it is hard work but can be creative and exciting if successful. Some seem to have decided that if the reader will skip around to find his/her own reading sequence, why do I need to suffer the hard work? Why not just embed my disordered paragraphs in a hypertext? I am further tempted to suggest that some intellectually lazy people with short attention spans saw hypertext as their easy salvation, or even that hypertext arrived just in time, and was welcomed, because it matches the culture of the one-line sound bite society.

But I digress! The other prick I wish to leave is to the common North American trait to be ignorant of, or even ignore and fail to reference, work from outside North America. Any review of hypertext is seriously incomplete without reference to the work of McKnight et al. (1991, 1993) final chapter. Finally, the major underlying HCI question here is how best to design usable electronic text: please refer to Dillon (1994) for both theory and sound practical advice.

The endpoint of the CSCW activity in writing an article, submitting it for refereeing, editing, and eventual publication, perhaps in hypertext form in an electronic journal, is the archiving and indexing for later retrieval and reading – so now we come to one of the latest areas for study, the so-called virtual or electronic or *digital library*. Since academic libraries are fast running short of storage space for the increasing flood of paper, any relief potentially offered by the computer is almost seen as a panacea, especially by those responsible for funding, despite librarians' misgivings about the reliability of electronic media for long term storage and about maintaining obsolete hardware and operating systems in the future to be able to read older material. (In Britain and the USA, initiatives for research on digital libraries are currently funded at £20 million and $24.4 million cf. Earnshaw, 1996; Follett, 1993; Fox, 1994).

Stimulated by the initiative, a series of annual conferences has been established in the USA of which the Proceedings of the second (latest) Digital Libraries'95 (Shipman et al., 1995) can be accessed on the World-Wide Web. The papers mostly appear to focus upon technical, librarianship, and software issues, which is understandable since the principal areas specified in the NSF call for proposals were data capture, advanced software and algorithms, and utilization of networked databases worldwide (Earnshaw, 1996). However, there was one paper on electronic journal aspects of relevance (McKnight, 1995a) and one on a hypertextual interface (Johanson and Cochrane, 1995). But HCI aspects do not appear yet to be given much attention although Earnshaw (1996) states

The key requirements for a digital library are:

- Usability, i.e., ease of use.
- Scalability, i.e., will it work with millions of simultaneous users?
- Sustainability [11] (p. 154).

thus placing HCI at the front.

In addition to the many issues already raised under electronic journals above and under CSCW and Hypertext/Hypermedia in the 1995 Readings, there seem to me to be two basic questions which need further attention for digital libraries. The first has been clear to me ever since I was able to do the first search with a real problem in a highly selected HCI database in BLEND (Shackel, 1985b); the power and speed of finding relevant items is much dependent on the selectivity of the database, but how can this be maintained amid the enormous growth in quantity of material and now even more so on the threshold of world wide digital libraries? Selectivity of sources and databases will be crucial to improve relevance in searches. This is where scientists, especially, but academics and researchers, in general, will need help from information specialists, even if eventually publishing becomes fully electronic (e.g., from scientist as author, direct to scientist as reader).

> Obviously this further development resulting from IT in the future could be helped by librarians and information scientists, but how best to achieve this? One possible solution is that all research grants should perhaps have an allowance only usable as payment into a community fund to employ an Information Officer who works solely for that particular research consortium (Shackel, 1989 (p. 160)).

The second is even more fundamental. Are the storage, indexing, and retrieval methods currently in use suitable for the future growth, and above all differences, in the types of users and in the tasks they will wish to do? Two papers (among several) point to this issue. Croft et al. (1995) report on experiences in providing widespread public access to US Government legislative information via the WWW; a major finding was that queries from the public used far fewer words (typically less than four) than would queries by experts: "Overall, our experience with the THOMAS system shows that it is very important to tune an information system to the user population" (p. 24). In Britain, Kidd (1994) studied the information retrieval requirements in office settings of 12 "knowledge workers" whom she suggests (giving reasons) may be considered representative of knowledge workers in general today. She describes their very different "typical" use of' information – essentially based on strong spatial memory for its layout around the office with little or no use of other storage – and thence she argues cogently that many of the assumptions currently underlying today's approaches to information storage and retrieval must he reexamined. Thus it is very clear that the Internet and digital/virtual libraries are already bringing a whole new set of users, task needs, and therefore problems in storage and retrieval, both in system organization and in HCI design.

From the above, I hope it is evident how interwoven are the issues in these areas of electronic journals, CSCW, hypertext, and digital libraries. Further, for the individual user, all these come together at his/her workplace; as noted in Fig. 6, the user needs an integrated system – one workstation to support E-mail/conferencing/journals/database search/and printing for off-line reading. I have recently purchased a "state-of-the-art" Macintosh with MSDOS card; with the software of today about six of the 11 facilities in Fig. 6 are available. But it does not have even one A4 page display for journal reading and, although it has good graphics, color and sound, the SVGA equivalent screen resolution nowhere near approaches that of a printed journal. Thus my HCI needs (as suggested over 10 years ago) are at best 60% satisfied. There is still much to be done.

7.5. From system design to interface usability and back again

In the early days of ergonomics work for computer systems, the human factors specialist (practitioner or researcher) was typically involved with many aspects of a whole system. So the focus of work was upon system design in the round, allocation of function, and the place of the human in the system (see, for example, the books by Sinaiko, 1961; Sackman, 1967; De Greene, 1970; Beishon and Peters, 1976). Interface design (often called "knobs and dials") was the logical endpoint of design but fitted in as time allowed. Even where detailed design topics were addressed, the orientation was still from a system viewpoint (e.g., Barmack and Sinaiko, 1966; Jones, 1970). As computing developed, especially with the microcomputer from 1980, the single user came to the fore and both research and application became focused upon the individual human's interaction with his/her specific computer, usually in an office environment. Interface details became paramount (cf. Shneiderman, 1987). Usability was recognized as the key concept, and was developed from a difficult target to a definable specification to be engineered and evaluated (cf. Shackel, 1981/84; Bennett, 1984; Bennett et al., 1984; Whiteside et al., 1988; Whitefield et al., 1991; Sweeney et al., 1993; Nielsen, 1993).

The huge amount of work on individual HCI has until recently overshadowed work on the group and system aspects. The latter work continued, however (cf. e.g., Damodaran et al., 1980; Mumford, 1983; Hirscheim, 1985; Eason, 1988; Klein and Eason, 1991), and its conceptual approach is gradually gaining ground. Although many design process prescriptions these days include fuller consideration of users, Eason (1988) reflects the broader approach:

> Many authors... consider that it is not sufficient to provide users with a formal role within a technically dominated design process. Hirscheim (1985), for example, considers that successful system design is primarily an exercise in organisational change and as such user-dominated socio-technical design methods should be employed (p. 28).

In the rest of his book, Eason then presents structures and techniques (as developed by the mid-1980s) for a systematic user-centred approach to the application of information technology in organizations.

Despite what has been done and written, for some time the technically dominated approach has been paramount. It is only now, with growing recognition of the many situations in which technically oriented designs have not succeeded in the market place or in the users' hands, that system designers in general have begun to accept the need to take the wider human, socio-technical approach from the start (cf. Eason and Harker, 1988). For example, Francik et al. (1991) describe how the WANG Freestyle system met difficulties exactly as the socio-technical authors have said should be anticipated during the design process (cf. Hirscheim and Newman, 1988). It is pleasing to see evidence of computer design groups recognizing the importance of this different approach. For example, Crocca and Anderson (1995) write:

> One outcome of looking at digital library systems as part of socio-technical systems that involve librarians, library users, engineers, libraries, computers, books, electronic documents, etc., is to take seriously the notion that the technologies and the practices associated with their actual use are co-developed and co-produced by all the participants (p. 7).

In the same conference proceedings, Lamb (1995) emphasizes the importance of designing for the much wider range of users to be expected in the future (as noted in Section 7.4) and reviews usability issues of on-line resource usage; she discusses HCI usability, content usability, organizational usability, and inter-organizational usability.

With regard to organizational issues, relevant studies have also been developed under the name "macroergonomics." Although a fair proportion of the papers are concerned with organizational topics in systems not involving computers or IT, nevertheless the proceedings of the four international meetings which have so far been held do contain relevant material (Hendrick and Brown, 1984; Brown and Hendrick, 1986; Noro and Brown, 1990; Bradley and Hendrick, 1994).

To develop methods and tools to aid with IT design for organizations, a CEC funded project was started in 1989. The plans for the project were outlined by Harker et al. (1990), and some of the results have been reported by Olphert and Harker (1994) and by Eason (1996). The ORDIT methodology offers an approach to describing system needs at organizational and work role levels; it supports a process of requirements generation, and enables developers and users to work together in exploring the potential impact of organizational and technical changes, and in evaluating possible alternatives. In particular, it uses the concept of responsibility modeling as a way of understanding how roles may change in a new, socio-technical system. The ORDIT methodology was tested through three case studies during development and already it is being used in two "real" projects by the researchers and also in others by non-research team developers. This is the type of approach needed to provide methods and tools which design teams can learn, adopt, and include as a basic part of the design process.

Thus, progress is bringing HCI full circle back to a proper recognition that the system context is crucial. Social and organizational factors will always strongly influence, if not dominate, outcomes; if HCI researchers and practitioners fail to deal with them, or to bring in relevant expertise to do so, then others will have to deal with them and probably at the expense of good HCI. So, much more attention than hitherto must be given to this wider orientation.

7.6. Other issues towards the future

There are other issues which cannot be developed because I have already taken much space. I mention a final few because they require much attention to HCI aspects.

From 1980 there have been concerns about possible health hazards and two main focuses of concern – the possible effects of radiation, especially for pregnant women, and the possible effects of intensive keyboard activity (named RSI – Repetitive Strain Injury). Many aspects of possible health hazards have been treated in Pearce (1984); the rise of RSI and the doubts have been well reviewed by Kiesler and Finholt (1988). A noteworthy difference in Europe is the broader approach to these issues, not focusing solely on the musculo-skeletal question but covering the whole workplace, work organization, and also the influence of the software being used (CEC, 1990).

With the move back to system design comes an important change in emphasis. Too often the inclusion of human factors in a design has depended upon the chance availability of a specialist. There is growing awareness of the need to ensure the involvement of user-centred design by structuring the design process to include a human factors strategy (Damodaran, 1991). Another aspect of building human factors into the design process is to develop standards at national and international level. Much is being done on standards for human-system interaction and software ergonomics (cf. Harker, 1995; Stewart, 1995; and the whole issue of *Applied Ergonomics* 26(4), 235–302, 1995, on international standards).

Finally, much is yet to be done on the specific HCI features needed for all the users of the future (including older, younger, and handicapped people), for new applications such as virtual reality, and for all the other new modalities (3D graphics, voice, gesture, etc.) of multimedia interaction.

8. Conclusions

In the last sections, I suggest that a number of issues have developed from past successes which remain to pose HCI problems for attention in the near future. In summary, the main ones are as follows:

1. For personal empowerment and real computer-aided working we need a large workplace with many and/or large displays – truly as described by the much quoted Vannevar Bush.
2. For the Internet/Web to be useful and used by people at large, we need better name servers or directory systems, and much simpler ways to store and retrieve everyday information that match the users and tasks of the future. As Croft et al. (1995) said, one must "tune an information system to the user population."
3. There are still many human factors and organizational aspects yet to be solved to improve the HCI for all computer-mediated communication as noted in Fig. 6.
4. Specifically for electronic journals, two basic questions for agreement or evolution are: What is the basic unit (or what is an electronic page), and how can we avoid confusing publishers, librarians, and especially readers with a multiplicity of journal handling software systems?
5. As the quantity of relevant information continues to grow overbearingly, we need to find standard ways of ensuring and paying for the specialized help (probably from librarians and information specialists) to manage the selective databases needed for high specificity.
6. At last HCI is growing out from the single user (ec)centricity and returning to the broader issues of system design. In doing so, we need to work even more closely with software design colleagues to build system design methodologies that include human factors strategies and are truly comprehensive.
7. Similarly, HCI must work with specialists, in social and organizational issues to help integrate these wider areas into the whole situation of information system design.

What are some of the topics and the HCI issues likely to develop over the next decade? Everyone will no doubt have their own preferred list, and comparing the results of Delphi studies with the actuality 5–10 years later shows that even such "best-guessed" predictions only seem to be about 50–60% valid. With that caution, my preferred list includes the following:

1. Some advances in HCI theory. It is fashionable to bemoan the lack of theory in HCI, but that does not make it entirely wrong; nevertheless, at the present stage of growth, I would still rather see plenty more pounds (or should I say kilograms) of substantiated fact and not worry too much about the paucity of ounces of theory.
2. Implications and possibilities of neural networks (taking over from AI and Expert Systems, which seem to be less potent and successful than expected); these may well assist with the theory question.
3. Environment is a fashion, but environmental control for better economy and less pollution is vital: humans need every help from useful IT to be better world citizens, and this may well start at home with the new developments in home IT systems – but all will be useless unless the HCI usability is especially good.

4. One of the new techniques which may help people to interact more easily with systems is the Smartcard; major developments can perhaps be safely predicted for this device.
5. The Smartcard may also help considerably with the major system problem of security. However to overcome the system problem of viruses, and to increase the probability of risk-free systems, will need much greater attention to many HCI issues.
6. An interesting development from several current capabilities, including especially games scenarios and multimedia, is the development of virtual reality systems. These have already existed for some time in the form of flight simulators to train air crew, for example, but are now being developed extensively; despite the "hype", the possibilities extend beyond the ephemeral gimmick to support the human exploration of new types of existence and consciousness without following the drug route.
7. The most significant area for future study starts from a fuller reading of the Japanese Fifth and Sixth Generation work, and reverts to one of the earliest papers (Licklider, 1960). By extensive studies aiming to understand and model better the interactive human, combined with the scientific learning which could be derived from virtual reality systems, we can envisage the possibility of Licklider's human–computer symbiosis coming much nearer to reality.

Editor's note

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Further reading

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