Human-computer interaction and CAI: A review and research prospectus

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Introduction

> None of the benefits of computer based instruction are inherent in
> computer based instruction...they all hinge upon the dedication, persistence
> and ability of good teachers and courseware developers....while technology
> can be a tremendous multiplier on good ideas, it does not, in itself, produce
> them. (Kearsley and others, 1983, p.94)

In recent years educators have become increasingly enthusiastic about the application of microcomputers in education. The potential of the 'cheap' computer appears to be greater than previous technologies. Teachers who have never touched a computer are enrolling in courses so that they become 'computer literate'. While the new technology can place a computer into each school or classroom for a reasonable cost, the problems of application and use of the technology, have not changed markedly from the time of early computer based education experiments in the middle 1960s.

In a recent review, Kearsley (1983) identified nine major outcomes of computer based instruction research. While Kearsley and his co-workers have identified an impressive series of developments, they highlight the lack of preparation provided for the average teacher. Faced with a growing amount of software and courseware, the novice teacher must examine the possible programs that are suitable for the particular subject and the approach the teacher wishes to adopt. Software is often described in brief terms that make practical judgements of its suitability extremely difficult.

A computer assisted information system consists of three major components: hardware, software, and the user (Figure 1). The interaction of these components is one of the important parts of the system - the human computer interface.
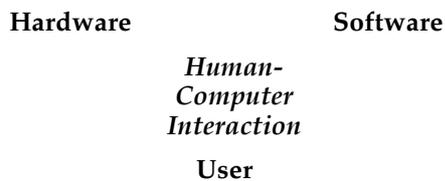
Hardware   **Software**

*Human-
Computer
Interaction*

User

Figure 1: Human-Computer Interface (from Bo, 1982)

This paper examines ways in which attributes of computer assisted learning systems can be matched with human cognitive skills.

It has been suggested by Jones and O'Shea (1982) that the perceived educational benefits of a computer system have little to do with the amount of use it gets. Instead, it seems that the quality and ease of the interaction are the most important factors. It is therefore argued that if human-computer interface can be improved, one further barrier to CAI use will be removed.

Human-computer interaction

It is significant to note that within the field of human-computer interaction there is a call for an increased emphasis to be placed upon the cognitive operations of the user. Thus, instead of designers of systems relying on 'folk psychology', Moran (1981) and Caroll & Thomas (1982) argue for an objective study of the user, and for computer systems designed to fit the user.

The lack of interest in a systematic study of the user as part of the human-cooputer system is not surprising given the classical-engineering equipment emphasis of many ergonomics/human factors studies. Reports summarising such research may be found in Willeges (1982), Didner (1982), Kearsley and Hillelsohn (1982) and Galer and Pearce (1980). Typically, only the physical design of electronic hardware has been considered (Shneiderman, 1980), which has lead to a concentration upon hardware and environmental issues of computer use (Shackel, 1980). Whilst this emphasis has clearly been successful in the effective development of ergonomically designed computing equipment, the broad claims of simplicity, naturalness or ease of use of new computer systems, languages or techniques are not based upon experimental confirmation (Shneiderman' 1980). Indeed, it is only very recently that the notion of 'user friendliness' has been taken seriously by hardware producers with the development of Apple's Lisa and Xerox' Ethernet (Micro Computer Printout, March 1983). As put by Didner (1982), until recently, problems of human-computer interaction has been a case of the 'tail wagging the dog', or instead of a computer being designed to support the users' activity, users have had to modify their activity to conform to whatever the system confronts them.

Whilst there has been increased interest in the study of users as a part of the human-computer system, most studies have been directed towards

experienced computer users - or more specifically, programmers. Early examples of these studies may be found in Martin (1973), Sackman (1970), Meadow (1970), Goos and Hartmanis (1977), Shneiderman (1978) and Buckingham (1977).

Several more recent papers deal more specifically with casual or novice users, for example: Mehlmann (1981), Radhakrishnan, Grossner and Benoliel (1982), Rouse, Rouse and Morehead (1982), Boyce (1982) and Morehead and Rouse (1982). These studies, however do not consider cognitive individual differences between users to be important.

Novice and expert users generally exhibit quite different modes of behaviour (Moran, 1981). The novice usually is engaged in problem solving activity, whereas the expert is skilled in interacting with the computer. Interaction is for the expert user a routine cognitive skill (Card, Moran and Newell, 1980). Moran believes that the only way to attain a coherent understanding of the user is to look behind the superficial features of the computer system and consider the user in psychological terms. He adds that the most promising approach may be the application of information processing models, which spell out the mental operations that the user must go through to accomplish given tasks. Only a few studies have taken up this issue - the application of information processing models to study the cognitive processes of novice and experienced computer users. Studies by Hoffman and Waters (1982), and Caffarella and others (1980) have indicated that users' personalities affect CAI effectiveness.

Whilst it is difficult to draw together such a wide range of research, the following tentative general points about human-computer interaction can be made:

1. there has been a large increase in the amount of human-computer interaction research over the past decade
2. the role of the user is being viewed to be of increasing importance
whilst users are an integral part of human-computer interaction, research to date has concentrated primarily upon programmers at the expense of novice users
3. individual differences between users have not been emphasised
4. very little research has emphasised the cognitive processes of users (programmers or non-programmers) as they interact with computer systems.

Design of computer assisted instructional materials

In general terms, the design of the human-computer interface has been left to 'educated guesstimates' about users and their requirements. This section of the paper attempt to derive some principles for the successful design of interactive computer systems by reviewing literature relating to the subject. It also suggests some areas of future research which emphasise the users' cognitive processes when interacting with computers.

The role of instructional design in computing has been stressed by Gagne (1982). He argues for instructional designers and computer programers to work together to produce computer based materials that take advantage of the particular features of the computer. He also notes that this process has been hindered by the commercial factor: it seems that programmers can turn out software that sells without considering the principles of instructional design. One of the most important factors that instructional designers can bring to computin. is the knowledge of the relationship between materials and cognition of the user. General concerns such as the best sequencing of conten or media or the amount of redundancy/ repitition needed are addressed by Briggs and others (1977) and Fleming and Levie (1978). These propositions remain untested in the case of computer based instructions.

User engineering principles
First principle: Know the user
 	
Minimise memorisation
    Selection not entry
    Names not numbers
    Predictable behavior
    Access to system information
Optimise operations
    Rapid execution of common
    operations
    Display inertia
    Muscle memory
    Reorganize command parameters
Engineer for errors
    Good error messages
    Engineer out the common errors
    Reversible actions
    Redundancy
    Data structure integrity
 	
User engineering principles for
interactive systems (Hansen, 1971).
 	
Introduce through experience
Immediate feedback
Use the user's model
Consistency and uniformity
Avoid acausality
Query-in-depth (tutorial aids)
Sequential - parallel tradeoff (allow
choice of entry patterns)
Observability and controllability
 	
Design guidelines for interactive
systems (Gaines and Facey, 1975).
	Simple. Project a 'natural',
	uncomplicated 'virtual' image of the
	system
	
	Responsive. Respond quickly and
	    meaningfully user commands
	User-controlled. All actions are
	    initiated and controlled by the
	    user
	Flexible. Flexibility in common
	    structure and tolerance or errors
	Stable. Able to detect user difficulties
	    and assist him in returning to
	    correct dialog; never deadening'
	    the user (ie, offering (no recourse)
	Protective. Protect the user from
	    costly mistakes or accidents (eg,
	    overwriting a file)
	Self-documenting. The commands
	    and system responses are self-
	    explanatory and documentation,
	    (explanations or tutorial material
	    are part of the environment
	Reliable. Not conducive to
	    undetected errors in man-
	    computer communication
	User-modifiable. Sophisticated users
	    are able to personalize
	    environment
	
	Interface design for time-sharing
	systems (Cheriton, 1976)

1. Use terse 'natural' language, avoid codes, allow abbreviations
2. Use short entries to facilitate error correction and maintain tempo
3. Allow single or multiple entries to match user ability
4. Maintain 'social element' to the communication
5. Permit user to control length of cues or error messages
6. Error messages should be polite, meaningful and informative
7. Give help when requested or when errors are in difficulty
8. Simple, logically consistent command language
9. Control over all aspects of the system must appear to belong to the user
10. Avoid redundancy in dialog
11. Adapt to the user's ability
12. Keep exchange rate in user's stress-free range; user can control rate

Ground rules for a 'well-behaved' system (Kennedy, 1974).

Simplicity
Power
User satisfaction
Reasonable cost

Software psychology (Schneiderman, 1980)

Know the user population
Respond consistently and clearly
Carry forward a representation of the user's knowledge base
Adapt wordiness to user needs
Provide the users with every opportunity to correct their own errors
Promote the personal worth of the individual user

Design guidelines for interactive systems (Pew and Rollins, 1975).

Provide a program action for every possible type of user input
Minimize the need for the user to learn about the computer system
Provide a large number of explicit diagnostics, along with extensive online user assistance
Provide program short-cuts for knowledgeable users
Allow the user to express the same message in more than one way

The design of idiot-proof interactive programs (Wasserman, 1973).

Forgiveness - ease in repairing errors
Segmentation - layered approach
Variety - choice of style
Escape - break out of danger
Guidance - direction and learning
Leverage - flexible, powerful features

The human-machine interface in a computerized conferencing environment (Turoff, Whitescarver and Hiltz, 1978).

When commmenting on the deliberations of the Software Psychology section of the British Psychological Society's 1979 Conference, Hale (1981) noted that a persistent theme of papers was the need for continued support of human factors studies dealing with human-computer interaction. Further, Kearsley and Hillelsohn (1982) have called for a systematic methodology for the process of involving users in the design and implementation of computer based training Systems. In the context of increasing use of computers for individualised instruction and computer assisted learning.

Barker (1982) has called for the development of a variety of interaction techniques that permit users to select modes of interaction that are best suited to their dispositions. He does not, however, refer to any such methods, nor list user dispositions that are likely to interact with performance whilst interacting with a computer. Stewart (1980) has been more specific in arguing for the rigorous testing of a number of guidelines for human-computer interaction. First, the layout and format of information needs to be tested on users. Second, user orientated formats should be tested on the actual equipment with real users before being finalised. Last, guidelines should not depend solely upon general principles, and the dialogue needs to be tested from the user's point of view. Stewart does not, however, couch his guidelines in terms of the cognitive processes of the users.

Broad ranging reviews of issues for the design of the human-computer interface have been discussed by Nickerson (1969), Bennett (1972), Martin (1973), and Miller and Thomas (1977). As noted by shneiderman (1980) however, the diversity of situations in which interactive systems may be used makes it difficult to prescribe a universal set of goals. Whilst very few attempts at this task have been directed specifically at CAI interaction, some have general applicability to the area. Shneiderman (1980) has reviewed the goals of various interactive systems designers, a summary of which are presented in Figure 2. Shneiderman's own list of goals is also presented in this Figure.

These goals of interactive systems design provide a useful set of guidelines for designers of CAI software. All of those who have used CAI will have not doubt been annoyed by materials that, for example, do not provide a working description of a program, contain inadequate messages, are inflexible and the like.

More importantly, however, these goals present the instructional designer with some of the variables of research into the design of CAI materials. Whilst all factors mentioned in these goals deal with the ways in which users process information, none is based upon research that has been couched in information processing psychology terms. In other words, the term 'user' needs to be specified with more cognisance of the individual differences between users. Put simply, if CAI materials are to be designed so that users can interact with them at a meaningful level, instructional designers need to study the cognitive processes with which users interact with such materials in a manner similar to that described by Saloman (1979) for visual media.

The goals listed in Figure 2 provide the basis of a prospectus of research into the cognitive processes with which users interact with computers and CAI materials. Such a prospectus would include some of the following factors.

- *User characteristics*
  Instructional designers should be aware of the likely user population, and thus the differences in cognitive processes that that they bring to the task at hand.
- *Simplicity*
  The notion of simplicity requires specification, as what is simple for some users may not be so for others. A detailed understanding of computer users' information processing skills is required before determinations of simplicty can be made.
- *Flexibility*
  It is apparent that CAI materials need to be flexible in a number of ways, such as providing for a wide variety of user input so as to capture the users' thoughts. Again, a detailed understanding of computer users' information processing skills will help determine the extent and nature of the flexibility that is required in CAI materials.
- *User control and feedback*
  If designers of CAI materials work with understanding of the ways in which users interact with computers, means to increase user control over learning will follow. One possible way of promoting user control is by the use of effective and appropriate feedback.
- *Error messages*
  Whilst it is apparent that error messages should be polite, meaningful and informative, research into what these terms mean for different users is required.
- *Format of materials*
  As with other areas of instructional design, research is required into the effectiveness of various formats of CAI materials on different types of computer users.

Conclusion

At the outset of this paper it was stated that study of a human-computer system must include the systematic study of the cognitive attributes of individual users. It was demonstrated that human-computer research has largely neglected these attributes, and thus the match between human and computer attributes is incomplete.

The interplay between psychology and computing may in fact be a two-way process. In the words of Caroll and Thomas (1982, p.115)

> Psychological theory and methods ... can provide a foundation for better interface design; but reciprocally, interface design provides a rich and detailed practical domain in which to assess and refine psychological theories of complex learning behaviour. Perhaps both disciplines are now mature enough to contemplate a serious relationship.

It is proposed that the effect of such research would be to remove some of the barriers to the use of computers in education. No longer would it only be the enthusiastic instructor who uses CAI programs, but a wider range of users would find it easier to interact with such materials.

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