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ABSTRACT

This paper provides an overview of past research on training employees for computer-mediated work. Recent literature is reviewed and critically analyzed using a four-part framework of individual differences and skill acquisition: sociodemographic factors, abilities and motivation, task constraints, and the man-technology interface. Furthermore, a conceptual framework is outlined for assessing training efforts using four dimensions: learning setting, teaching method, duration of skill acquisition and frequency of training, as well as computer ergonomics. The review of existing research indicates that most studies are based on a narrow disciplinary focus, thereby ignoring important intervening variables which might help explain learning outcomes. Several other fundamental concerns regarding existing research are identified and discussed. This article concludes with projections for the future based on past research and the present research climate. (45 references) (Author)

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Computer Technology and End-User Training: An Integration of Information Processing and Man-Machine Interface Perspectives[1]

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Running head: Computer Technology and Skill Acquisition

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Computer Technology and End-User Training: An Integration of Information Processing and Man-Machine Interface Perspectives[1]

Abstract

This article provides an overview of past research on training employees for computer-mediated work. Recent literature is reviewed and critically analyzed using a four-part framework of individual differences and skill acquisition: sociodemographic factors, abilities and motivation, task constraints and the man-technology interface. Furthermore, a conceptual framework is outlined for assessing training efforts using four dimensions: learning setting, teaching method, duration of skill acquisition and frequency of training, as well as computer ergonomics. The review of existing research indicates that most studies are based on a narrow disciplinary focus, thereby ignoring important intervening variables which might help explain learning outcomes. Several other fundamental concerns regarding existing research are identified and discussed. This article concludes with projections for the future based on past research and the present research climate.

Computer Technology and End-User Training: An Integration of Information Processing and Man-Machine Interface Perspectives[1]

Few people would dispute that it would be a good idea--before spending several hundred dollars on ski equipment, going to the top of the steepest hill available, pointing the skis downward and pushing off--to take a skiing lesson (or two). Training would provide the skier with the practical and theoretical knowledge, and the confidence, that he or she needs to perform well on the slopes; training (e.g., ski lessons) before purchasing the equipment would also ensure optimal use of the expensive gear thereafter. What seems self-evident when applied to skiing should appear equally so when applied to the end-user computer domain. Only through training can expensive information technology be successfully implemented, because only training can provide workers with the skills and confidence needed to ensure efficient computer use.

Training in end-user computing has developed rapidly during the past two decades; it is the scene of much effort and activity, and, as a consequence, of much controversy and confusion. Empirical studies abound but are seldom linked to conceptual schemes, typologies, or theories. The following is an attempt to inject some order by reviewing current issues and emerging trends: (a) clarifying key terms as typically used in the skills and training field; (b) presenting a conceptual framework for assessing training; (c) surveying and critically evaluating representative studies according to the schemata provided by specifically discussing research about acquisition of computer skills; (d) presenting research implications and future needs; and (e) providing implications for practitioners. What distinguishes this review from earlier ones in the area is that it tries to discuss and integrate research from a variety of disciplines such as cognitive and educational psychology, sociology, management and man-technology studies (e.g., ergonomics[1]). Further, the goal is to provide breadth of coverage, without making the review exhaustive -- rather, articles were selected for their ability to convey the state of end-user training research and to stimulate readers' ideas for future research and practice.

Why are answers to the above issues important? Computer technology will soon be one of the largest capital asset items for many organizations (e.g., approximately 30% of total capital assets in financial and service firms, Zarley, 1988), and if the company is to reap the benefits of its huge financial investment, the workforce must possess the necessary skills to make efficient use of the new computer-based technology. The question must be asked: What are the successful training strategies for skill acquisition needed to ensure efficient computer-mediated work by a firm's workforce? Moreover, it is important to assess how individual differences, physical environment, workstation design or just simply the man-technology interface[2] could affect training effectiveness and, consequently, how well end-users will make use of new technology. Answers to the above issues will assist our attempt to provide end-user training programs which fit both individual and organizational needs.

PART 1: A SHORT REVIEW OF TRAINING ISSUES IN END-USER COMPUTING

Definitions of "end-user computing" (EUC) and "skills" are fundamental to any discussion of training. After clarifiying these terms, this section will outline a definition of computer skills.

Broadly defined, EUC as used in this paper's context encompasses the application of information technology (often a networked PC) by employees who do not necessarily consider themselves to be computer specialists. Just as it is possible for a person to be a competent driver without being a mechanic, today's end-user can have the required skills to make efficient use of the various computer hardware and software without necessarily being a technical specialist.

Definition of Skill

It would be useful if we could provide the reader with a simple definition of skill, but the term is not one which is easily defined; indeed, analysts have been struggling with its meaning for decades (see Adams, 1987 for an extensive historical review). Recent theories of learning, however, provide one method of narrowing the term's interpretation by convincingly pointing to a distinction between knowledge about something (declarative knowledge) and knowledge of how to do something (procedural knowledge) (Ackerman, 1987).

To elaborate, this indicates that "skills" encompasses such diverse activities as skiing, typing, cooking a meal or doing a firm's financial consolidation and inventory management using a computer and special software. Ackerman (1988) argued that each of these skills is subsumed in a finite domain of behaviours. Moreover, he stated that such skill specifications necessarily exclude a variety of non-motor learned behaviours, such as chemistry problem solving and abstract reasoning.

A working definition of "skills" must be established. Adams (1987) attempted to do so in a recent review of human motor skills research, and for the treatment of skill acquisition in this paper, the three defining characteristics as outlined by Adams are used: He stated that "(1) skills are a wide behavioral domain in which behaviors are assumed to be complex. (2) Skills are gradually learned through training and (3) attaining a goal is dependent upon motor behavior and processes" (Adams, 1987, p. 42).

Computer skills. These could be defined as: *Using various means of training, computer skills are learned behaviours needed for achieving desirable performance levels when doing job related tasks using a computer; achieving satisfactory performance hinges first upon attentional resource capabilities (i.e. information processing) and motor behaviour by the individual and, second, upon the mix of declarative and procedural knowledge needed to perform the skill.*

Complex computer-mediated tasks require more declarative knowledge than less complex ones (e.g., data-entry) thereby raising the amount of time needed for training to achieve satisfactory performance levels (Schneider & Fisk, 1982).

The rationale for investigating skill development and enhancement in the computer-based technology domain is threefold: (1) Computer skills are necessary for efficient technology use by employees (Klein, Hall & Laliberte, 1990); (2) More and more organizations and government agencies are spending vast amounts of money on skill training in the end-user computing domain, hoping to facilitate the efficient use of information technologies (Leontief & Duchin, 1986; Panko, 1987); (3) Knowledge of how to promote efficiency in computer training and achieve results commensurate with investment is lacking. Several researchers point out that the vast majority of literature in the training domain is atheoretical in nature, and more conceptual work is needed (e.g., Campbell, 1971; Goldstein, 1980; Wexley & Baldwin, 1986). Work beyond the field of information systems management (e.g., Sein, Bostrom & Olfman, 1987), such as cognitive and educational psychology (see Ackerman, 1987; Lepper 1985, Rhodes, 1983 for extensive literature reviews) has been generally ingnored. These oversights will be addressed below in more detail.

PART 2: ABILITIES, TRAINING AND SKILL ACQUISITION

Part 2 will first outline a three phase typology which has been used by cognitive psychologists to describe the learning phases a person may go through in training. Then, the ways skill acquisition is affected by individual differences and the task-technology interface will be discussed using a four-part framework (cf. Table 1). Finally, a conceptual framework for training will be outlined and past research will be reviewed as it applies to this structure (cf. Table 2).

A Three-Phase Skill Acquisition Typology

Recent research has stressed that skill acquisition is ordinarily a continuous process consisting of progressive stages which describe the learning process (Adams, 1987), and has centred on perceptual learning. Schneider (1985) proposed a model in which performance improvements are gained by a shift of information processing from a serial to a parallel mode. Phase 1 requires controlled processing since all cognitive or attentional resources are required by the individual to comprehend and learn the performing of a yet unfamiliar task. Processing of two tasks occurs in serial fashion. According to Ackerman (1987) Phase 3 represents a situation in which automatic information processes are predominant. These processes are

> "characterized as fast effortless (requiring minimal cognitive resources), and unitized (or proceduralized) in such a way that they may not be easily altered by a subject's conscious control; they may often allow for parallel processing with other information processing components within and between tasks." (Ackerman, 1987)

Phase 2 represents a combination of controlled and automatic information processes. While for certain portions of the task the individual has developed fast and effortless parallel processing of information, other task components still require full use of cognitive resources. Thus, according to Shiffrin (1985), task performance is still sensitive to memory and resource-load effects.

As implied by Adams (1987) and suggested by Shiffrin's (1985) model, training should help an individual to progress from controlled to automatic processing. To illustrate, learning the required skills for solving calculus (financial acounting) problems first requires the acquisition of declarative knowledge to enable use of the necessary problem-solving steps to achieve the task objective. Once the individual understands the principles and concepts imbedded in calculus, he or she will then have to practise this new skill. Controlled and automatic processing of information will be needed at this stage of the learning process (Phase 2) to solve the problems. After extensive practice (which will differ between individuals depending upon ability) the individual should be reaching Phase 3 enabling automatic processing when solving the problem, thereby increasing work performance. Thus the problem-solving task has essentially become an automatized skill being done efficiently and with little effort (Ackerman, 1988, 1987).

How does the above relate to end-user computing? For using a word-processor or spreadsheet effectively it is hoped the individual will pass through the three learning phases, thereby eventually reaching Phase 3 which enables automatic processing. Thus, reaching automatic processing through training allows the employee to prepare and execute responses to skill demands without conscious reflection. This is when the monotonous repetitions of silly sentences or commands pays off and the user's finger responds to the letter "a" or a certain program message by automatically hitting the correct letter or function key on the keyboard.

Individual Differences, Man-Technology Interface and Skill Acquisition

Although both the individual and the organization would benefit if training could speed transition through the three phases of learning, this process will depend upon individual differences and the man-technology interface. The following sections will describe the individual differences and the man-technology interface as outlined in the four-part framework of Table 1. The framework is based upon Ackerman's (1988) work but has been expanded to apply to technology by, first, adding the individual's motivation to learn as an important variable (cf, Lepper, 1985; Lepper & Gurtner, 1989) and secondly, expanding the framework with a fourth dimension, namely, the man-technology interface. (Card, Moran & Newell 1983)

Sociodemographic factors. Rhodes (1983) reported that age failed to account for more than 10% of the variance in performance across a variety of attitudinal and performance dimensions. Fossum et al. (1986), reviewing the skills literature, however, reported that older employees are more vulnerable to skill obsolescence because their last formal training is likely to have been some time ago; furthermore, older employees see a weaker linkage between improving current skills and obtaining rewards, so have less incentive to upgrade. There are also significant memory differences between young and old employees. A study by Craik and McDowd (1987) tested the differences between young (average 20.7 years) and elderly adults (average 72.8 years) performing cued-recall and recognition tests while carrying out a choice reaction-time task. The results indicated that there was a reliable age decrement in recall, leading the authors to conclude that older people perform more poorly on recall tasks than they do on recognitiion tasks. Recall requires more processing resources and such resources are generally depleted as people grow older.

Gender may also affect skill acquisition (cf. Table 1), and reasons for gender differences are always being sought. For instance, Vollmer (1986) reported that men's and women's perceptions of their abilities vary; men generally perceive their level of ability to be higher than do women, and tend to see themselves as more instrumental. The differences in academic achievement recorded in Vollmer's sample may be due to women's lower opinion of their abilities, which leads them to expect less of themselves. Freedman and Phillips (1988), reviewing the literature dealing with gender-based effects, report that many of the differences obtained in numerous studies were due to women having lower expectancies then men for such things as careers, salary, occupational achievement and training.

Insert Table 1 about here

Abilities and motivation. Defining cognitive and intellectual abilities is a complex and difficult task. Humphreys (1979) suggested that a broad definition of intelligence should be used, and defined intelligence as "the resultant of the processes of acquiring, storing in memory, retrieving, combining, comparing, and using in new contexts information and conceptual skills; it is an abstraction". Humphreys (1979) produces evidence which suggests that intelligence is best measured by using a general intellectual ability factor (or *g*) and within any hierarchical matrix the *g* factor (i.e. the general factor loadings) is likely to be larger and account for much more variance than the various group factors.

Vernon (1961) suggested that the *g factor could be responsible for 20 to*

40 percent of the total variance obtained for a variety of ability tests. Hence, *g* represents the most general ability, while less general factors are placed lower in the hierarchy (Ackerman & Schneider, 1985). Based on their literature review, Ackerman and Schneider (1985), as well as Humphreys (1979), suggest that *g* is usually not represented as a single ability but, instead, as a communality of processes and behaviours which are pertinent to any type of intellectual task.

Another factor influencing skill acquisition is perceptual speed ability (cf. Table 1). Werdelin and Stjernberg (1969) state that "the perceptual speed factor is a measure of the capacity to automatize, by means of practice, the solution of perceptual problems, which have originally depended on the visual-perceptual factors " (p. 192). The third factor influencing skill acquisition is the person's psychomotor ability. A definition of the term is as follows: "psychomotor ability represents individual differences in the speed (and accuracy) of motor responses that are characteristic of psychophysical limitations of the human subject" (Ackerman, 1988).

The final factor influencing skill acquisition is, of course, the subject's motivation and expectancy. Putting more effort into learning skills (e.g., via additional practice) can compensate for low ability. For instance, Gettinger (1985) reported that allocating insufficient learning time has a direct, negative effect on achievement, while Keith (1982) reported that homework has compensatory effects, i.e. the low-ability student who spends one to three hours per week on homework gets the same grades as the average-ability student who spends no time on homework.

Wentzel (1989) reported that high-school students with a high grade-point average (GPA) had multiple goals which inlcluded being dependable and responsible as well as learning and understanding things, while average and below average GPA students frequently pursued such goals as making friends and having fun. Hence, high expectancy on the part of the individual as well as performance related goals should effect learning outcomes positively (Natriello

& McDill, 1986).

Motivation and cognitive abilities may, however, have different effects depending upon the type of knowledge to be acquired. For instance, Kanfer and Ackerman (1988) reported that giving goal assignments during learning for procedural knowledge was more dysfunctional for the lower ability students, conversely for the declarative knowledge condition, goal assignments were particularly beneficial for the low ability students and helped them concentrate on task activities. These results suggest that the traditional management framework, which recommends goal-setting as a means of improving job performance (e.g., Locke & Latham, 1984) does not necessarily apply for skill acquisition. In fact, goals may be detrimental to the learning process when individuals must acquire procedural knowledge and are trying to achieve a level of learning which permits parallel processing of more than one task (e.g., moving a block of text [a column of numbers] within a document [to another document] and being on the phone), thereby increasing their work-speed.

Task constraints. It is hypothesized that increasing the degree of positive transfer-of-training from previous experience allows learners to commence a task at a superior performance level to novice learners. For instance, a skilled-typist who is phased with learning a program upgrade (e.g., a new upgraded version of the word-processing software he/she usually uses) faces limited cognitive demands, since a transfer of knowledge from using the program previously (the "old" version) will occur. The basic structure and features (e.g., command keys needed to move text) of the upgraded version of the program will probably be the same as used in the previous version, and thus familiar to the user. Nonetheless, the add-on features offered in the upgraded version of the program will first require the use of cognitive resources for understanding and processing this new information. With some practice, the individual will automatize the performance of job-related-tasks using the new or changed program features, thereby again reaching Phase 3 of skill acquisition.

Research also shows that this line of reasoning applies to mathematical problem solving as well. For instance, Novick (1988) found that when two mathematical problems share structural features but not surface features, spontaneous positive transfer is more likely in experts than in novices.

In some cases, however, computer technology may be used to redesign the structure and responsibilities inherent in a position, thereby increasing task complexity. This in turn increases the demand upon the individual's cognitive resources, thereby limiting the transfer-of-training from a previous job situation. Thus, learning may again start in Phase 1.

Cognitive demands during Phase 1 learning are similar to various degrees of task consistency. If consistency between various job tasks or their components is limited, demands upon the cognitive and attentional apparatus are increased (Ackerman, 1988). More importantly, inconsistent tasks will make it difficult to move beyond Phase 1. In such an instance, the "labour in vain" effect may occur, so that increased practice does not substantially increase performance (Nelson & Leonesio, 1988).

The man-technology interface in this context includes the physical work and learning environment (e.g., ambient temperature, light, and colors) and computer ergonomics[3] (e.g., design of of hardware and software). For instance, Vicente and Williges (1988) reported that using a graphical interface, when searching a hiearchical file system on a computer, reduced within-spatial ability group variability in performance. Moreover, Egan and Gomez (1985) reported that older individuals and people with low spatial memory have more difficulty in learning a text editor.

Another factor to be considered is the learning environment. For instance, research has reported that while women prefer an ambient temperature of 24° Celsius men prefer 21° Celsius for working or learning (Ellis, 1984). Moreover, Rosenfield, Lambert and Black (1985) reported that students seated in circles engage in significantly more on-task behaviour than those seated in rows or clusters. Training or classroom environments which encourage group learning or de-emphasize the dispersion of report card grades also reduce the perceived dispersion of ability levels by pupils (Mac Iver, 1988), and co-operative learning environments increase the status of female students (Johnson, Johnson & Stanne, 1986).

Another important factor, as a trainee with previous computer experience may benefit from transfer of learning while a novice may not, is the user's skill level (Nelson & Leonesio, 1988). Lamberti and Newsome (1989) compared the speed and accuracy of high-skill and low-skill programmers when learning an expert system using abstract or concrete information. The results indicated that high-skill subjects performed better on questions requiring abstract information organisation than novices, while the latter performed better on questions requiring concrete information organization using the expert system.

The man-technology interface in conjunction with task constraints, abilities and motivation of the individual, and sociodemographic factors all profoundly affect the skill acquisition process (see also Table 1). Hence, a successful training strategy must take these factors and their interrelationship into consideration (cf. Lepper & Gurtner, 1989).

<u>A Conceptual Framework for Computer Skills Training</u>

To move from controlled processing to a mix of controlled and automatic processing, or to solely automatic processing when doing a task requiring computer skills, can be accomplished only through practice and training. The learning environment and the teaching method used may be other important variables influencing skill acquisition and learning outcomes. The following sections will describe the training process as outlined in the conceptual framework of Table 2.

<u>Learning setting</u>. Various learning settings are being used to teach computer skills (cf. Table 2) while comparisons of their respective feasibility for acquiring different skills have not been extensively tested. Based on our earlier discussion each setting seems to have certain advantages which, due to space limitations, cannot be discussed fully here. Classroom teaching may be

used to facilitate the acquisition of declarative knowledge in the learning process while the laboratory (e.g., computer lab or flight simulator) should facilitate the individual's progress ir o Phase 2 of the skill acqusition process (mixed cognitive and automated processing of task relevant information) (cf. Gattiker, 1990; Kanfer & Ackerman, 1989).

On-the-job training may be used to help the individual further practice newly acquired skills, thereby attaining a level of automaticity in performing job-related-tasks. For an organization, a combination of classroom, laboratory and on-the-job learning may be quite likely. However, research using these learning settings and testing their effect upon learning performance is non-existent for all practical purposes (Burke & Day, 1986).

Teaching method. As Table 2 indicates, numerous teaching methods are being used to train students and employees. For instance, Hall, Rocklin, Dansereau, Skaggs, O'Donnell, Labiotte & Young (1988) investigated individual differences in the recall of procedural and structural/functional information in situations in which students studied in dyads (cooperative learning) or alone. The results showed that students who studied together recalled significantly more than did those who studied alone. Dossett and Hulvershorn (1983) reported that less able individuals profited from peer training via computer-aided instruction (CAI), while highly able students were kept back when this teaching method was used.

Even though new technology such as videos and CAI have become very popular, the verdict as to whether these methods actually increase teaching effectiveness is not yet in. For example, Hativa (1988), using a longitudinal design, reported that CAI and practice in arithmetic widened the gap between high- and low-achieving students. Additionally, a meta-analysis of managerial training studies reported that when looking at learning outcomes, the behavioural modelling approach still seemed to be the most successful training method when compared to others such as CAI, peer training and self study (Burke & Day, 1986).

Duration and frequency of skill acquisition. As outlined earlier, literature suggests that for relatively complex tasks more than four hours of training and skill practice is needed to elimininate performance differences based on an individual's cognitive resources (Ackerman, 1988). Much of the organizational and educational training literature reports, however, are on studies which are of very short duration, while only a few investigations done in educational institutions describe experiments with a duration of more than a week (e.g., Gettinger, 1985; Keith, 1982).

Literature would also suggest that an intermittent approach to training appears more fruitful than a continuous one. Intermittent training gives the trainee the opportunity to practice newly acquired skills, thereby attaining a higher level of automaticity. The amount of time needed to improve performance will depend upon the individual's motivation and expectancy as well as ability (e.g., *g* factor). Intermittent training allows the individual to take the necessary time between sessions to do the assignments thereby individualizing the learning process (Kinsner & Pear, 1990).

Computer ergonomics. Software as well as hardware can affect the learning of a student. For instance, eye strain and postural complaints can result from visual-display-terminal luminance, oscillation degree, face and legibility of characters and keyboard design (Fellmann, Bräuninger Gierer & Grandjean, 1982). Östberg, Shahnavaz and Stenberg (1989) compared the legibility of a single-colour display with dark characters on a whitish background (positive polarity) with the legibility of an IBM PC colour monitor on which blue characters were presented on a dark blue-grey background (negative polarity). They found that the IBM PC colour monitor had a significantly lower legibility than the standard display. Doing a word-processing task, the researchers found that subjects using the IBM monitor made more reading mistakes and character confusions than the subjects using the single-colour display.

Software ergonomics may also affect learning. Studies show that, for instance, spreadsheet calculation systems are more easily learned if formula trees are kept simple (Saariluoma & Sajaniemi, 1989). Having a "mouse"[4] and/or menu always present during training increases the mean task completion time of these subjects compared to subjects who had neither condition available during learning (Davies, Lambert & Findlay, 1989). Conversely, having specific interactive software commands can further shorten the time required for skill acquisition for a new software package (Barnard, Hammond, MacLean & Morton, 1982).

Another issue is names used by a computer program for naming files and commands. Carroll (1982) compared "congruent" with less congruent command languages for software packages. Carroll (1982) defined a language as being congruent if "functional relations between command definitions are mirrored in structural relations between commands". Hence, robot commands to get the technology to raise and lower its arm should have names such as up/down or raise/lower instead of up/lower and raise/down which Carroll (1982) considered to represent ingongruent command language. His data indicates that the learning and using of filenames and commands is facilitated if their linguistic forms are structured to reflect functional interrelations between their referencts (i.e. they are congruent). Similarly, Barnard, Hammond, MacLean and Morton (1982) reported that text-editing software using semantically specific command terms allows them to be learned using less help functions, thus reducing the training time needed.

PART 3: COMPUTER SKILLS ACQUISITION: CHALLENGES AND OPPORTUNITIES

Part 1 outlined a definition for computer skills while Part 2 schematized how individual differences and the man-technology interface affect skill acquisition (cf. Table 1) and outlined a conceptual framework for computer skills training (cf. Table 2) by reviewing literature in education, ergonomics, management, sociology, and psychology.

Part 3 discusses research about training in the field of end-user computing. The three-part framework (cf. Table 1) and the conceptual framework for training (Table 2) outlined earlier will provide the necessary structure for reviewing the literature. In each of the subsequent sections, the literature in the end-user computing and training domain is examined, followed by an assessment of the limitations of previous research. In summary, the following sections will show that research about computer skill acquisition has three major characteristics: 1) effects of task constraints upon skill acquisition are largely ignored, 2) neither the effects of duration of skill acquisition nor frequency of training's effects upon learning and performance have been investigated, and 3) most research is done in educational rather than organizational settings.

Individual Differences, Technology-Task Interface and Computer Skill Acquisition

Past research has investigated the effects of gender on learning and computer skill acquisition. For instance, Johnson, Johnson and Stanne (1986) used eighth grade students in their study, and reported that girls did better in a cooperative learning environment than a competitive one during computer skill acquisition. Further, Anderson (1987) reported that high school females performed better than males in problem analysis when it came to certain programming tasks. Gist, Rosen and Schwoerer (1988) reported that older trainees (over 45 years) exhibited significantly lower learning performance than younger trainees (average = 20.7 years) when acquiring computer skills in their four hour training program.

Gattiker (1990) reporting on a series of studies with management students in an undergraduate university course, concluded that lower ability students were able to transfer practice effort into higher learning performance when acquiring procedural computer skills. The data also indicated that transfer of learning from a previous computer course, taught by the computer science department, had a significant effect on learning for high ability students, when acquiring declarative knowledge, but not for procedural knowledge (cf. Ackerman, 1988).

Ergonomics can also affect the student's perception of a computer and his or her motivation to learn about the machine. For instance, computers may be perceived as having certain personalities and thus affect user compatibility. Penrose and Seiford (1988) reported on a study comparing the perception of Apple Macintosh computers versus IBM PC or XT by users and non-users of each machine. Comparing users' and non-users' perceptions of the two types of computer revealed that the Macintosh was perceived as easier to use, happier, less expensive and more personal while the IBM PC seems more technical, formal, expensive and professional. The data also indicated that Mac users may be be somewhat more opinionated and zealous in their support of the Macintosh and their antagonism toward IBM, than are IBM users about their machines and toward the Macintosh. Penrose and Seiford's (1988) study suggests that the computer's and user's personalities must be taken into consideration when designing programs and writing documentation for the user. A user profile may, therefore, support an effective man-technology interface.

Potential limitations in past research. Although the above review is definitely not complete, when taken together with the conceptual framework outlined in Table 1, several weak spots in skill acquisition research in the end-user computing domain can be identified. First, we were not able to locate research which assessed the effect of perceptual speed ability or psychomotor ability upon learning performance. Another area of concern is that the literature does not identify the level of complexity of the skills to be acquired during the computer training. As previous sections in this paper have shown, however, performing efficiently when doing complex tasks does require more training. Thus, accomplishing Phase 3 (automatic processing) may be a lengthy process if the subject has to perform complex tasks.

How the level of task consistency affects the individual's performance when learning computer-mediated tasks (cf. Table 1) is also rarely researched. The higher the consistency (e.g., entering orders taken over the phone into the computer versus decision making), the easier it will be for the employee to acquire the speed needed to perform the task by automating some cognitive processes (Ackerman, 1987). Moreover, a recent review of this literature concluded that past studies have generally, with some notable exceptions, (e.g., Craik & McDowd, 1988; Gist, Rosen & Schwoerer, 1988) concentrated on younger (below 30 years of age) subjects without assessing the potential effects of age on learning. Additionally, research has still failed to explain the cause of gender-based differences; some literature suggests that these learning differences may be due primarily to different socialization processes for each gender (e.g., Vollmer, 1986; Jacklin, 1989) and not to such factors as intelligence and ability (Humphreys, 1979).

The lack of research dealing with the man-technology interface and learning is more disturbing than other commissions. Although much research has been published about human-computer interaction and how people learn certain software programs, such research is usually not linked to the vast amount of literature dealing with training and learning in other fields (Kitajima, 1989). For instance, we were not able to locate research which dealt with the effect of the potential interrelationship of individual differences and computer ergonomics upon learning performance.

Another concern which must be mentioned is that past literature has usually used novice learners when teaching computer skills. However, rapid change in computer hardware and software can lead to skill obsolescence unless training providing skills upgrading is offered to the end-user. It is probable that task constraints and the man-technology interface (see also Table 1) may require different teaching methods and learning settings for the high-skill user in contrast to the novice (e.g., Nelson & Leonesio, 1988).

A further concern is how the interrelationship of individual abilities, motivation and software ergonomics may affect learning. This is still largely unknown and research is non-existent for all practical purposes. To illustrate this, how sociodemographic factors may interrelate with work and learning environment needs (e.g., light, VDT display and software command structure) is not known. Research which indicates that a restriction of program features helps novice learners when acquiring new skills needed to use the software is helpful (e.g., Carroll & Carrithers, 1984); however, reasons and explanations for these results must be given to advance our knowledge and understanding of learning processes in the EUC domain.

Table 3 presents a descriptive taxonomy of research, in education and training as well as industrial psychology and ergonomics, dealing with the moderating variables as identified in Table 1 and their potential effect upon skill acquisition.

Insert Table 3 about here

Table 3 represents a summary and indicates that, first, limited cross feeding and integration of research results is occurring between work in education and training and work in industrial psychology and ergonomics. Although both research streams are engaged in the area of sociodemographic factors, and their potential effect on learning, there is little if any collaboration between the two streams (e.g., as evidenced by the lack of citations from the other body of literature.) Secondly, while industrial psychology and ergonomics have concentrated on the man-technology interface, education and training specialists have researched the effects of motivation and excpectancy and, to a limited extent, the influence of task constraints upon skill acquisition. While one effect of ability upon computer skill acquisition has been largely ignored, neither of the two research thrusts integrate or overlap to a substantial degree. This would suggest that our knowledge about the moderating variables' direct and intermediate effect (through interrelationships) upon computer skill acquisition is limited and more research is needed to close this knowledge gap.

Training Factors and Computer Skill Acquisition

Research about training and skill acquisition in end-user computing has flourished within the last decade (Hebenstreit, 1985). Nevertheless, as the discussion below will show, most research can be classified into one or two areas (cf. Table 2) thereby neglecting other areas which require study in order to advance our limited knowledge.

The following sections will basically reveal three interesting facts by using the framework outlined in Table 2: (1) In most studies the frequency of training is continuous (e.g., every working day during one week); (2) most training efforts are short term; and, (3) very rarely is more than one teaching method used, which does not allow for comparison between methods and learning outcomes.

Learning setting. We could find only a few studies which apply cognitive and training concepts to the domain of end-user computing and skill acqusition in an organizational setting using high-skill employees. In some technology studies, computer training is treated as one of many issues. For example, Bikson, Gutek and Mankin (1987) reported that classroom settings were rarely used to train employees for computer skills. Instead, the majority of training was given on-the-job. Most research about computer training is, however, done in laboratory or educational settings (e.g., universities), as is the case in the training and educational literature research outlined earlier in this paper.

Bayman and Mayer (1988) reported on a study using a laboratory setting to teach Basic, while Anderson (1987) reported on a classroom setting used to teach Basic. Gattiker and Paulson (1987) reported data using both the classroom (mostly to teach declarative knowledge about Basic) and a laboratory setting (to teach procedural knowledge about Basic using the computer). The latter study indicated that lower ability students were more able to close the performance gap when learning procedural knowledge, since practice increased the automaticity of solving tasks using the Basic programming language (e.g., Gattiker & Paulson, 1987).

Teaching method. Bayman and Mayer (1988) presented data which suggests that students learning Basic computer programming with a method emphasizing the underlying semantics (e.g., conceptual models) developed fewer misconceptions, and performed better on transfer tests of programming skills than their colleagues taught with a manual emphasizing the language's syntactic features. Gist, Rosen and Schwoerer (1988) reported that computer-aided-instruction (CAI) was less helpful than behavioural modeling (i.e. subject observes instructor doing the task on the computer first and then tries to do it him or herself using the computer) in computer skill acquistion.

Gattiker (1990) reported that the performance dispersion between ability groups was smaller when using the hands-on laboratory setting, which required students to apply their skills using the computer, than when using a classroom setting to teach computer skills. The literature discussed here suggests that a hands-on teaching approach, using the behavioural modeling technique, may be more beneficial for lower-ability students than other teaching methods.

Duration of skill acquisition and frequency of training. Gist, Rosen and Schwoerer (1988) reported on a study which taught Lotus (spreadsheet software) to people of various ages. The duration of training was limited to approximately three hours and one time block was used. In contrast, Barnard, Hammond, MacLean and Morton (1982) used intermittent training (two sessions - two weeks apart) to teach individuals interactive comands for text-editing software. Initial training was limited to a couple of hours.

I ed (1985) used 40 minute experiments to test how the effect of computer graphics and their use may improve estimates to algebra work problems. Vicente and Williges (1989) reported on a study in which, during an experiment, individual differences were accommodated when searching a hierarchical file system by providing a graphical interface. Subjects were given 2.5 hours of training to learn the system while Davies et al. (1989) provided novices with 40 minutes of training to learn a text-editor before assessing the subjects learning performance. In summary, studies dealing with duration and frequency of skill acquisition are generally limited to less than four hours of training and intermittent training is rarely used.

Computer ergonomics. Computer ergonomics have been shown to affect learning outcomes. For instance, presenting abstract information about a problem to be solved with the help of the computer reduces performance by low-ability individuals, while performance increases on concrete information organization (Lamberti & Newsome, 1989). Other research indicates that difficulty in le rning and remembering the command vocabulary needed to communicate with a computer-based information system can be reduced if semantically specific terms are required to use certain software (Barnard, Hammond, MacLean & Morton, 1982).

Legibility of visual display screens is another factor which should facilitate learning and reduce health complaints (cf. Fellmann, Bräuninger Gierer & Grandjean, 1982; Östberg, Shahnavaz & Stenberg, 1989). Creed, Dennis and Newstead (1988) reported that displaying a paragraph of text for proof-reading with visual-display units was preferred by subjects and led to increased accuracy, although the speed was somewhat reduced. The few studies mentioned here indicate that there is a growing awareness that ergonomics can affect the man-technology interface and learning.

Potential limitations in past research. The most interesting phenomenon about training in end-user computing may be that most studies do not report an assessment of training methods in organizational settings using employees as subjects, and comparing novices with high-skill users. Instead, students are often being paid a small fee for participting in laboratory studies (e.g., Reed, 1985; Vicente & Williges, 1989). Hence, the sample may not be representative of the larger population (e.g., motivation to participate and age distribution of sample, cf. Table 1).

Most training is of short duration (up to approximately four hours) (e.g., Bayman & Mayer, 1988; Davies, et al., 1989). Is this sufficient time for people to acquire an understanding of the program and task requirements (Phase 1)? Moreover, did they have enough time to improve performance, speed and accuracy through practice (Phase 2), or to automate some skills to reduce the cognitive resources required to perform certain tasks efficiently (Phase 3) (e.g., Bayman

& Mayer, 1988; Gist, Rosen & Schwoerer, 1988)?

It seems that the above questions must be answered negatively for several reasons. First, stability of performance between subjects is attained after the first three hours of training on relatively simple cognitive tasks only. Since learning computer skills (e.g., hardware and various software such as a text-editor for a PC) is a complex task, additional hours are needed to move an individual beyond Phase 1 of skill acquisition (cf. Ackerman & Schneider, 1985). Secondly, most studies have not differentiated between declarative and procedural knowledge. A particular teaching method, in combination with differences in time spent practicing, might be more suitable for acquiring either type of knowledge (i.e. declarative versus procedural).

Another area where more research is needed is the potential effects of intermittent versus continuous training on computer skill acquisition. Most studies use continuous training over a short period of time, which does not enable the assessment of effects on learning of such intervening variables as motivation and time spent practicing newly acquired skills. A final concern may be that in most cases, unfortunately, one, or possibly two teaching methods are used and compared for their learning outcomes in only one learning setting (e.g., classroom or on-the-job setting). Instead more studies are needed assessing more than one teaching method and comparing learning outcomes evolving out of at least two different learning settings (cf. Lepper, 1985; Snow, 1986).

Table 4 represents a summary and indicates, once again, limited cross-feeding and integration of research results is occurring between work in education and training and industrial psychology and ergonomics. Nonetheless, both areas have investigated the effects of laboratory settings and behavioural modeling, as well as continuous training, upon computer skill acquisition. Secondly, while industrial psychology and ergonomics have concentrated their research efforts upon computer ergonomics by looking at hardware and software design effects upon computer skills acquisition, education and training have primarily focussed on the learning setting and teaching method's effects upon computer skill acquisition (cf. Table 4).

Insert Table 4 about here

As Table 4 suggests, neither of the two research streams has investigated duration and frequency of skill acqusition beyond continuous training. Moreover, our knowledge about the interrelationships between the moderating variables and computer skill acquisition is limited and more research integrating the findings from both research thrusts is needed to advance our knowledge. Last but not least, research about computer skill acquisition is often not linked to the larger issues of training as outlined in Table 2 but, instead, has a narrow focus without much relation to the skill acquisition domain in general.

PART 4: CONCLUSIONS AND PROJECTIONS FOR THE FUTURE

Training end-users to acquire the necessary skills needed to perform efficiently with new computer-based technology is as fundamental a topic as any that exists in human resource management. This review tries to provide an overview of some of the ideas and research that are relevant to an understanding of the processes and dimensions involved in a comprehensive training scheme for acquiring computer skills in many work settings. Clearly it is not exhaustive.

Part 1 outlined the issues encountered specifically in end-user training and a definition of computer skills was developed. In Part 2, a three phase typology for describing the learning phases a person may go through in training was outlined. Also discussed was a four-part framework for individual differences as well as the man-technology interface and their potential effect upon skill acquisition (Table 1). Lastly, a conceptual framework for technology-induced training was presented (Table 2).

Part 3 reviewed the literature using the frameworks developed. The review indicated that training research in end-user computing tends to avoid dealing with individual differences and task constraints. Evidence was provided to show that a distinction between acquiring procedural knowledge (how to do something) versus declarative knowledge (knowledge about something) is very rarely made by research dealing with computer skills acquisition. Moreover, neither organization-based training efforts nor a distinction between continuous and intermittent training are studied enough, thereby leaving this field wide open for additional research.

Implications for research. What inferences can we draw from past trends and the present research climate to project directions for research? Tables 3 and 4 outlined how two different bodies of literature have investigated the computer skills acqusition and training domain.

There are several ways of getting to the core of the end-user training challenge and advancing our knowledge by using our present store of ideas and methods:

1) It should be underscored that there is little, if any, interdisciplinary collaboration between education and training research on the one hand, and industrial psychology and ergonomics on the other (see also Tables 3 and 4). This is unfortunate, as each discpline contributes necessary but insufficient insight. The bodies of research reviewed here often exist in splendid isolation from one another. Interdisciplinary research would contribute greatly to the understanding of this important area of inquiry.

2) Although the research must continue to examine various components and alternative training strategies, it will move forward more effectively if (a) the research about training for computer literacy is based within the larger training framework of such disciplines as managerial training, education and cognitive psychology, (b) both short- and long-term training effects upon learning outcomes, are investigated, different teaching methods and learning settings are used and compared for learning outcomes, and (c) a more theoretical and cumulative focus is adhered to.

3) Moderating variables' effect upon learning outcomes, such as continuous vs. intermittent training, learning expectancy and motivation and

man-technology interface needs study. Such research will help in designing training programs which best fit the needs of novice and high-skill users, thereby improving learning outcomes and the effective use of technology for computer-mediated job related tasks.

4) Dual-task processing in the EUC domain must be assessed to increase our knowledge about the computer skill acquisition process. Such positions as the one of a mail-order clerk, whose dual-task is to communicate with the computerized ordering system at the same time as he or she is taking an order over the phone, should be studied to test how much automation and parallel processing of the two job related tasks (i.e. taking the order over the phone and entering it onto the computer system) is actually happening, and where and why sequential processing may prevail. Such studies will (a) increase our knowledge about how extensive training helps in progressing through the three learning phases as outlined by Ackerman (1988), (b) test and extend the generalizations about the controlled and automated processing made in the field of perceptual learning, and (c) show how interferences (e.g., customer talking on the phone) may reduce processing speed when performing a dual-task using the computer (e.g., entering the order onto the computer system).

Implications for training specialists and management practice. Although computer training is a diverse field, making generalization somewhat difficult, the following impress us as some major trends and developments which should be considered when embarking on a training program for computer literacy in an organizational setting.

1) Computer training is becoming an increasingly expensive endeavour for most organizations, especially for small firms which often do not have the necessary computer know-how to provide in-house training. Thus, a decision must be made between providing training in-house by hiring an outside specialist or sending employees to outside facilities. The latter may be the more economical if the firm can make use of courses and/or facilitates offered by educational non-profit institutions such as universities and colleges.

2) From a personnel planning point of view, managers and employees must determine together when skill obsolescence is becoming an issue, thereby making upgrading a necessity to ensure satisfactory performance.

3) Learning outcomes must be assessed looking at both the subjective and the objective dimensions. Such data are required for determining the utility of any training program sponsored or paid for by the organization.

4) Both computer ergonomics and individual differences, as outlined in Table 1, must be considered when designing or selecting training programs for computer skill acquisition by employees.

5) To facilitate the transition from controlled to automatic processing of task-related information, thereby increasing performance levels, an individual should have unlimited access to the computer to practice the newly acquired skills as much as he or she feels necessary or is motivated to.

6) Job complexity and autonomy may further decide about the mix of declarative and procedural knowledge the individual must acquire to perform satisfactorily when doing computer-mediated tasks. An individual's cognitive resources and motor skills will influence the time element required to learn the skills needed to succeed when doing computer-mediated tasks which are job related.

The above suggestions are not, of course, all-encompassing, but they do illustrate that decisions about training efforts in the area of computer skills requires careful planning and decision-making. Moreover, continuous change in technology will require more frequent training for most employees to avoid skill obsolescence, thereby making a careful consideration of the issues outlined in this paper a necessity.

FOOTNOTES

1) Ergonomics is a science which is concerned with the study of the functional relationship between human beings and technology such as computers. Ergonomics considers characteristics of people when designing and arranging technology and workspace, thereby helping to increase the effectiveness and safety of interaction.

2) The man-technology interface could be defined as encompassing the critical factors for success to be considered before and during the acquisition of new technology and making the necessary adaptations leading to organizational change (e.g., workflow, job related tasks and organizational structure). Thus, man-technology interface looks at the physical context of work (e.g., work station design, illumination, ambient temperature, privacy and social interaction, and also visual and acoustical privacy) as well as technology ergonomics (e.g., ergonomics of hardware such as the visual-display terminal (VDT) and keyboard design, software ergonomics and user friendliness of technology applications). Hence, successful man-technology interaction leads to a healthy work environment and supports the employee's and firm's efforts toward a high quality of work life for technology users.

3) Computer ergonomics is the study of computer useability and encompasses all the human factors that are relevant to computer design and use.

4) A "mouse" is a pointing device to select items on a video screen. It is a small box set atop wheels or ball bearings and attached to the keyboard with a wire to improve maneuverability. Rolling the mouse on the table will cause analogous movements of the cursor on the video display. Buttons protruding form the top of the mouse can be used to select certain commands and actions.

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Table 1

Individual Differences, Technology-Task Interface and Skill Acquisition: A Four-Part Framework

SOCIODEMOGRAPHIC FACTORS	ABILITIES AND MOTIVATION	TASK CONSTRAINTS	MAN-TECHNOLOGY INTERFACE
-Age -Gender	-General Ability -Perceptual Speed Ability -Psychomotor Ability -Motivation and Expectancy	Level of: -transfer of learning -complexity -consistency	-Learning Environment -Computer Ergonomics -Novice versus Skilled User

Table 2

A Conceptual Framework for Computer Skills Training

LEARNING SETTING	TEACHING METHOD	DURATION AND FREQUENCY OF SKILL ACQUISITION	COMPUTER ERGONOMICS
-classroom -laboratory -on-the-job -combination of the above	-computer-aided learning (CAI) -behavioural modelling -peer training -self-study -goal setting -combination of the above	-hours/working days of training Type of training: -continuous -intermittent	Hardware - workstation design -mouse and/or keyboard design -visual-display terminal Software Design - command structure - vocabulary

Table 3

A Descriptive Taxonomy of Research about Moderating Variables Affecting Computer Skills Acquisition

RESEARCH ON MODERATING 1) VARIABLES AFFECTING SKILL ACQUISITION	EDUCATION AND TRAINING 2)	INDUSTRIAL PSYCHOLOGY AND ERGONOMICS
SOCIODEMOGRAPHIC FACTORS 3)		
-Age	Yes	Yes
-Gender	Yes	Yes
ABILITIES AND MOTIVATION		
-General Ability		
-Perceptual Speed Ability		
-Psychomotor Ability		
-Motivation and Expectancy	Yes	
TASK CONSTRAINTS Level of:		
-transfer of learning	*	
-complexity		
-consistency	*	
MAN-TECHNOLOGY INTERFACE		
-Learning Environment	Yes	
-Computer Ergonomics	Yes	
-Novice vs. Skilled User		*

Note: No mark indicates that research pertaining to these moderating variables and and skill acquisition for technology-mediated work could not be found.

* = Research dealing with this area is scarce.

1) Research assessing the interrelationship between moderating variables is extremely scarce.
2) Includes studies from such disciplines as education, management, cognitive psychology and sociology.
3) Some research in either Education and Training or Industrial Psychology and Ergonomics integrating findings from both streams of research can be found.

A Descriptive Taxonomy of Research on Computer Skills Training

RESEARCH ON TRAINING 1) CHARACTERISTICS AND COMPUTER SKILLS ACQUISITION	EDUCATION AND TRAINING 2)	INDUSTRIAL PSYCHOLOGY AND ERGONOMICS
LEARNING SETTING		
-classroom	Yes	
-laboratory	Yes	Yes
-on-the-job	Yes	
-combination of the above	*	
TEACHING METHOD		
-computer-aided learning (CAI)	Yes	
-behavioural modelling	Yes	Yes
-peer training	Yes	
-self-study		
-goal setting	Yes	
-combination of the above	*	
DURATION AND FREQUENCY OF SKILL ACQUISITION		
-hours/working days of training		
Type of training:		
-continuous	Yes	Yes
-intermittent		
COMPUTER ERGONOMICS		
Hardware		
-workstation design		Yes
-mouse and/or keyboard design		Yes
-visual-display terminal		Yes
Software Design		
-command structure		Yes
-vocabulary		Yes

Note: No mark indicates that research pertaining to this area of technology related training could not be found. If both major research streams do studies on a training characteristics domain, considering and integrating of research findings from the other stream is limited.

* = Research dealing with this area is scarce

1) Research assessing the interrelationship between moderating variables is extremely scarce.
2) Includes studies from such disciplines as education, management, cognitive psychology and sociology.

Appendix 16

END

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