DOCUMENT RESUME

ED 334 409 CE 058 431

AUTHOR	Gattiker, Urs E.
TITLE	Computer Skills Acquisition: A Review and Future Directions for Research.
PUB DATE	Aug 91
NOTE	49p.
PUB TYPE	Information Analyses (070)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Basic Skills; Cognitive Psychology; *Cognitive Style; Computer Assisted Instruction; *Computer Literacy; Computers; Demography; Foreign Countries; *Human Factors Engineering; Industrial Psychology; Instructional Design; Job Skills; Learning Theories; Motivation; Personal Autonomy; Psychomotor Skills; *Skill Development; Training Methods; *Transfer of Training

ABSTRACT

A review of past research on training employees for computer-mediated work leads to the development of theory and propositions concerning the relationship between different variables, such as: (1) individual factors; (2) task and person-computer interface; (3) characteristics of training design for the acquisition of computer skills; and (4) the learning outcomes. Most studies are based on a narrow disciplinary and methodological focus, ignoring important intervening variables that might explain learning outcomes. The propositions are as follows: (1) the effect of perceptual speed and psychomotor abilities on skill acquisition is moderated by the level of complexity; (2) the effect is magnified by the level of task consistency; (3) the person-computer interface affects the performance of novices more than experienced computer users, older users more than younger ones, and individuals with below average ability more than high ability persons; (4) deficient declarative and procedural knowledge about basic, social, and conceptual skills will increase training time; (5) if these skills are deficient, intermittent training will significantly increase learning and performance; (6) motor/cognitive ability limitations will be reduced by using a variety of teaching methods; (7) training effectiveness will increase if training integrates past experiences and demonstrates relevance to job applications. Projections for the future are based on past research and the present research climate: (1) limited integration of research results is occurring between work in education and training, personnel psychology, ergonomics, and cognitive psychology; and (2) research must continue to see if the propositions are in fact cross-culturally valid. (Four figures, 3 tables and 94 references are included.) (NLA)

AUGUST 91

Computer Skills Acquisition: A Review and Future Directions for Research[1]

Urs E. Gattiker[2]
University of Lethbridge
Alberta, CANADA
and
Stanford Center for Organizations Research
Stanford University

Running head: Computer Technology and Skill Acquisition

[1]This paper greatly benefitted from the insightful comments made by Philip L. Ackerman. Usual disclaimers apply. I would also like to thank Suzanne Kiely and HelenJane Shawyer for their editorial assistance in preparing this manuscript. Financial support for this research project was in part provided by the Labour Market Evaluation Branch, Alberta Career Development and Employment, Contract No. 497-77-89 and the Social Sciences and Humanities Research Council of Canada Contract No. 494-85-1022. The views expressed in this paper are the author's own and are not necessarily shared by these organizations.

[2]Comments requests for reprints should be addressed to Urs E. Gattiker, Lethbridge Center for Organizations Research, Faculty of Management, The University of Lethbridge, Lethbridge, Alberta, T1K 3M4, CANADA. Telephone: (403) 320-6966; Electronic Mail: Gattiker%HG.UNCAEDU.BitNet or Gattiker@HG.ULeth.CA; FAX: (403) 329-2038.

Computer Skills Acquisition:

A Review and Future Directions for Research

Abstract

This article provides an overview of past research on training employees for computer-mediated work. The article develops theory and propositions concerning the relationships between (a) individual factors, (b) task and person-computer interface, (c) characteristics of training design for the acquisition of computer skills and (d) the learning outcomes, namely the computer skills acquired by the employee. The review of existing research indicates that most studies are based on a narrow disciplinary and methodological focus, thereby ignoring important intervening variables which might help explain learning outcomes. Using the framework presented in this paper, several other fundamental concerns regarding existing research are identified and discussed while propositions for further empirical investigations are outlined. This article concludes with projections for the future based on past research and the present research climate.

Computer Skills Acquisition:
A Review and Future Directions for Research

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 (Panko, 1987). 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 through: (a) clarifying key terms as typically used in the skills and training field; (b) presenting a conceptual framework to assess training; (c) surveying and critically evaluating representative studies according to the schemata provided by specifically discussing research on the acquisition of computer skills; (d) presenting research implications and future needs; and (e) providing implications for practitioners. This review is distinguished from earlier ones in the area in that it tries to discuss and integrate research from a variety of disciplines such as cognitive and educational psychology, sociology, management and person-computer studies (e.g., ergonomics[1]). Further, the goal is to provide breadth of coverage, without making the review exhaustive. Articles were selected for their ability to convey the state of end-user training research and stimulate readers' ideas on 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 (approximately 30% of total capital assets in financial and service firms) (Zarley, 1988). If a company is to reap the benefits of its huge financial investment, the workforce must possess the skills necessary to make efficient use of the new computer-based technology (Gattiker, 1988). The question must be asked: which training strategies for skills acquisition will ensure efficient computer-mediated efforts by a firm's workforce? Moreover, it is important to assess how individual differences, physical environment, workstation design or the person-computer interface[2] could affect training effectiveness and, consequently, how well end-users make use of new technology. Answers to the above issues will assist our attempt to provide end-user training programs which fit <u>both</u> individual and organizational needs.

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

Broadly defined, end-user computing (EUC), as used in the context of this paper, encompasses the application of information technology (often a networked PC) by employees who do not necessarily consider themselves to be computer specialists. Today's end-user can possess the required skills to make efficient use of the various computer hardware and software without necessarily being a technical specialist.

Before discussing how individual differences in combination with training methods may affect learning outcome, it is necessary to first discuss which skills the individual requires to perform effectively when doing computer-mediated tasks. Unfortunately, the EUC literature does not provide the reader with a clear picture on this subject. In fact, the skill literature indicates a bimodal distribution between the assumption that skills are either individual (holds certain type of skills) or job centered (skills are inherent in job based on task design and workflow)[3].

<u>Definition of Skill</u>

<u>Cognitive psychology</u>. It would be useful if we could provide the reader with a simple definition of skill, but the term is not easily defined; indeed, analysts have been struggling with its meaning for decades (see Adams, 1987; Spenner, 1983 for extensive historical reviews). Psychological studies have mainly concentrated on the learning of skills (i.e., behaviors) through training, in which goal accomplishment is dependent upon the level of declarative and procedural knowledge[4] required to perform satisfactorily (Ackerman, 1988).

A working definition of "skills" must be established. Adams (1987) attempted to do so in a recent review of human motor skills research. He proposed three defining characteristics: "(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).

Insert Figure 1 about here

Figure 1 graphically illustrates how psychologists have attempted to discuss and define skills. Each individual has certain motor behavior abilities which may be high or low as indicated by the vertical axis in Figure 1. In addition, an employee or student has a certain level of cognitive process ability (e.g., abstract reasoning and decision-making). Each individual may have a different "ability" curve, and may not, in fact, make full use of his/her abilities. Training design and content must consider this mix of abilities carefully when planning an appropriate training module.

Industrial sociology. Sociological thought shifts attention from the individual to the firm or job, and states that skills are multidimensional (Spenner, 1983; 1990). Specifically, substantive complexity refers to the level, scope, and integration of mental, manipulative and interpersonal tasks in a job. Autonomy-control, the second dimension, alludes to the discretion or leeway available in a job to control the content, manner, and speed with which tasks are done (Spenner, 1983). However, similar to psychology literature, industrial sociology provides no consensus on a definition of the term beyond the general, as outlined herein (e.g., Attewell, 1987, 1990; Hall, 1986, pp. 23-26; Kalleberg & Berg, 1987, p. 176; Spenner, 1983, 1990).

Insert Figure 2 about here

Figure 2 graphically illustrates the two dimensions suggested by sociologists for defining job skills. The assumption is that the job defines which skill demands must be met by any job holder to accomplish a person-job fit. Substantive complexity and autonomy-control have been reported to correlate between .50 and .70 (e.g., Spenner, 1990).

Using Weberian theory as a base, sociologists tend to see skills as an intrinsically relational phenomenon, which is dependent on the number and types of individuals capable of performing a given task (rather than the complexity of the task itself), the supply and demand for people to carry out these tasks, incumbents filling these positions, and those being excluded (e.g., gender segregation). To put it differently, if tasks being performed in a job are perceived by society as being valuable, and only a few people are able to perform these tasks, the skill will be highly valued (e.g., high financial rewards). Labor economists would argue that this reflects a human resource dependency: limited supply for a high demand increases price (e.g., starting salaries for electronic engineers in the 1990s). Hence, these social valuations creeping into job descriptions and reward systems are not necessarily biases but a critical aspect of the phenomenon itself (Attewell, 1990).

Defining computer skills: An interdisciplinary approach. Figures 1 and 2 illustrate that the individual's mental and cognitive abilities may, (1) determine what type of skills he/she can learn/acquire during training and, (2) influence the performance level to be obtained when applying a skill. In turn, substantive complexity and autonomy-control by the job affects the type of skill needed for satisfactory performance. In the context of this paper we assume that computer skills represent both a learned behavior and mental processes. Computer skill, as used in this context, implies mundane accomplishment in mastering a task, while high performance suggests superior or virtuoso application of that skill (cf. Attewell, 1990).

Using the relational phenomenon, as utilized by Weberian theory, skills can be categorized using their potential ease of transferability (e.g., to another job and/or employer). Gattiker (1990a, chap. 12; 1990b) proposed such a categorization, and suggests that transferability of skills decreases from basic (reading, writing and arithmetic), social (e.g., interpersonal and person's ability to organize his/her own effort and task performance, and possibly that of his/her peers and subordinates), conceptual (includes planning, assessing, decision making about task-and people-related issues, and judging or assessing tasks done by self or others), technology (encompasses appropriate use of technology, such as a computer, thereby preventing breakdowns/accidents), technical (physical ability to transform an object or item of information into something different), and finally, to a person's task skills (usually job-specific).

The above five skill categories reiterate how important the respective approaches of sociology and psychology are to the skill domain. For instance, writing speed and success in planning tasks will depend upon the person's abilities (see Figure 1). How important writing speed and conceptual skills are to perform well, depends in turn, upon job demands. Simply put, limited substantive complexity and high autonomy-control in one's job will reduce the demand upon one's social and conceptual skills. This will reduce the requirements upon the person's abilities. Hence, an integration of these two approaches to the skill topic seems quite helpful when defining computer skills which we consider to be part of the technology skills category (Gattiker, 1990a, chap. 12; 1990b):

> *Using various means of training, computer skills are learned behaviors needed for achieving desirable performance levels when doing job related tasks, while the content and type of computer skill required for doing a job is in part a relational phenomenon (i.e. how many and what type of people have or don't have the necessary skills). Achieving satisfactory performance (during learning and, there-fter, on-the-job) hinges first upon individual abilities (motor and cognitive process capabilities, e.g., information processing), second, the degree of substantive complexity and autonomy-control offered/required by the job and third, upon the mix of declarative and procedural knowledge the person has in basic, social, conceptual, technology, technical and task skills before training starts as well as the mix to be acquired during training.*[5]

Based on the relational component of the above definition, certain computer skills may be used to discriminate against certain groups (e.g., natives and blacks). Moreover, the relational approach to skills would suggest that training during childhood and adolescence (e.g., primary and high school) as well as continuous education may largely determine the skill-base available to employers. Consequently, a firm's decisions regarding work-design and workflow may be largely influenced by this (Gattiker, in press; Van Houton, 1987)[6]. Thus, if a skill becomes too scarce, an employer may reduce the job's skill demand (e.g., substantive complexity) by simply re-organizing the workflow. Lowering the skill demand for the job holder results in potential de-skilling for the latter (Shaiken, Herzenberg & Kuhn, 1986). This, in turn, will lower human resource dependence for the firm, since a increasing applicant pool for job openings (i.e. more people are now qualified to perform the de-skilled job-related tasks) will facilitate recruiting, selection and training of new hires. The above illustrates how the relational approach to skills as used in sociology, can help in further understanding the skills concept.

Insert Figure 3 about here

Figure 3 graphically illustrates the interrelationship between the individual (abilities) and the job-skill (substantive complexity and autonomy-control) dimensions. Thus, both cognitive (individual focus) and sociological (job focus) perspectives have been included in this framework. Most important, abilities as well as substantive complexity/autonomy-control affect each other. This suggests that the debate in industrial sociology attributing up-skilling and/or de-skilling effects to new technologies can be best addressed by considering the reciprocal relationships between abilities and job demands. Limited use of various abilities during training (formal schooling, university and apprenticeships) may limit the individual's capability to cope with complexity and autonomy in his/her work. In fact, over the years, limited substantive-complexity and autonomy-control on the job/at work lowers the individual's intellectual flexibility (Kohn & Schooler, 1983). Once ability (e.g., intellectual flexibility) is reduced, this in turn can affect the person's ability for future skill upgrading due to technology or other work-related developments (Gattiker, 1990b).

Another strategy for reducing the potential gap between computer skills held by employees and job demands is, naturally, providing training (e.g., in-house or through paying employees to attend continuous education classes at the local college). Similarly, if skills offered by the firm's workforce are beyond what is required by current jobs, upgrading of current jobs can take place by redesigning the workflow. In short, numerous options exist and different scenarios may apply in various work-settings. In the context of this paper, we are primarily interested in the training option.

PART 2: INDIVIDUAL FACTORS, TASK AND TRAINING DESIGN: DEVELOPING A MODEL

Figure 3 outlined graphically how current skill levels may be affected by the individual's abilities and job demands (i.e. use of skills on-the-job). Organization change and development may, however, necessitate workflow and job design adjustments resulting in a different skill mix being required to perform adequately. For instance, while in the past keyboard skills were very important for acquiring a secretarial job (e.g., typing speed and accuracy tests given to applicants), today's job advertisement often states that a knowledge of computer skills, especially, word-processing and spreadsheet software, is a definite asset if not a requirement. Thus, typing speed has become less important (e.g., typos can be corrected when running the document through a spell-checker).

In today's labor market, the organization may be able to hire people who possess exactly the skills and know-how needed for the job. More likely, however, the firm will find individuals who meet part of the skill requirements only. In such an instance, training given to the individual (e.g., on-the-job or a course at a training facility) may provide the necessary skills-upgrading required to perform adequately.

Insert Figure 4 about here

Figure 4 illustrates the interrelationship of job demands and an individual's abilities, how this relationship may affect skill levels and, most importantly, how these relationships may interrelate with training. To illustrate this further, it is obvious that accountants will receive different training for learning a word-processing program than will secretaries, because they use the program differently (i.e. job demands), have different skill levels (e.g., accountants might currently lack typing proficiency) and will probably have different ability levels (e.g., cognitive ability for numbers).

Figure 4 schematically illustrates how these interrelationships influence the type and content of training possible for skill acquisition. The following sections will review research dealing with these issues by discussing, first, how individual abilities may affect learning, second how job demands may influence the learning process (e.g., learning tasks which are continuous versus discontinuous) and third, how training design and delivery influence the skill acquisition process.

Individual Factors

The following discussion is organized around (a) the relationship between sociodemographic factors and (b) the abilities and motivation of the individual with learning outcomes; namely computer skills needed by the employer for satisfactory on-the-job performance of computer-mediated tasks. Thus, literature has not only looked at human abilities but also at characteristics in order to learn more about the skill acquisition process.

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. However, Fossum, Arvey, Paradise and Robbins (1986), reviewing the skills literature, 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 weak link between improving current skills and obtaining rewards and, therefore, have less incentive to upgrade. Also, significant memory differences between young and old employees were found.

A study by Craik and McDowd (1987) 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 recognition tasks. Perhaps because recall requires more processing resources, and such resources are generally depleted as people grow older.

Gender may also affect skill acquisition (cf. Table 1). 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 in their successes, rather than attributing it to luck. 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 on gender-based effects, reported that many of the differences obtained in numerous studies were due to women having lower expectancies than men have 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) broadly 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) produced evidence which suggests that intelligence is best measured using a general intellectual ability factor (or *g*). Within any hierarchical matrix the *g* factor (i.e. the general factor loadings) is likely to be larger and to 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 behaviors which are pertinent to any type of intellectual task.

Another factor influencing skills 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 skills acquisition is one'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). Hence, keyboard skills are affected by the accuracy and speed of motor responses executed by an individual's hands (Leggett & Williams, 1988).

The final factor influencing skills acquisition is, of course, the motivation and expectancy of the subject. 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. Also, high expectancy and performance related goals on the part of the individual should affect learning outcomes positively (see also the earlier discussion on gender effects) (Natriello & McDill, 1986).

Motivation and cognitive abilities may, however, have different effects depending upon the type of knowledge to be acquired. Results of a study by Kanfer and Ackerman (1989) 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 skills 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 at the same time), thereby increasing work-speed.

Task and Person-Computer Interface: Required Job Skills

The following discussion is organized around (a) the relationship between task constraints and (b) the person-computer interface with learning outcomes; namely computer skills necessary for the employee to perform satisfactorily computer-mediated tasks on-the-job. As Figure 2 suggests, substantive complexity and autonomy-control are two factors which will affect the time required to learn new skills or achieve satisfactory speed when doing the task (e.g., Ackerman, 1988). In addition, general and psychomotor ability as well as perceptual speed and motor abilities (see above section and Figure 1) will influence the time requirements for skill acquisition (Ackerman, 1987; Gattiker, 1990c; Humphreys, 1979).

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 than novice learners. For instance, a skilled word-processing typist who must learn an upgraded version of a program faces limited cognitive demands, as a transfer of knowledge from the previous program will occur (see also Table 2). 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. However, in some cases, computer technology may be used to redesign the structure and responsibilities inherent to 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.

Cognitive demands during the initial phase of learning a new skill 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 make it difficult to increase one's performance. In such an instance, the "labor in vain" effect may occur, so that increased practice does not substantially increase performance (Nelson & Leonesio, 1988).

Insert Table 2 about here

Work environment and person-computer interface. In the context of this paper, the term includes the physical work and work environment (e.g., ambient temperature, light, and colors) and computer ergonomics[7] (e.g., design of hardware and software). 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). An ideal work or learning environment would require a satisfactory ambient temperature. Gender differences in the temperature preference would require a compromise (e.g., 22°-23° Celsius)[8].

Another factor to be considered is the work and program design. For instance, Vicente and Williges (1988) reported that when using a graphical interface to search a hierarchical file system on a computer, the variability of performance was reduced within the spatial ability group. Moreover, Egan and Gomez (1985) reported that older individuals and people with low spatial memory have more difficulty learning a text editor. Lamberti and Newsome (1989) compared the speed and accuracy of high-skill and low-skill programmers learning an expert system which used abstract or concrete information. The results indicated that high-skill subjects performed more successfully on questions requiring abstract information organization than did novices, while the latter performed better on questions requiring concrete information organization.

Software as well as hardware can also affect student learning. 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-color display with dark characters on a whitish background (positive polarity) to the legibility of an IBM PC color monitor, on which blue characters were presented on a dark blue-grey background (negative polarity). They found that the IBM PC color monitor had a significantly lower legibility than the standard display. The researchers found that subjects performing a word-processing task using the IBM monitor made more reading mistakes and character confusions than subjects using the single-color display.

Software ergonomics may also affect learning (see also Table 2). Studies show that spreadsheet calculation systems are more easily learned if formula trees are kept simple (Saariluoma & Sajaniemi, 1989). Having a "mouse"[8] and/or menu always present during training increases the mean task completion time of these subjects compared to those with neither condition available while learning (Davies, Lambert & Findlay, 1989). Conversely, specific interactive software commands can shorten the time required for skills acquisition of a new software package (Barnard, Hammond, MacLean & Morton, 1982).

Another issue is the file names and commands used by a computer program. Carroll & Carrithers (1984) compared "congruent" with less congruent command languages for software packages. A language was defined as congruent if "functional relations between command definitions are mirrored in structural relations between commands." Robot commands 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 & Carrithers (1984) considered as representing incongruent command language. His data indicate that the learning and using of filenames and commands is facilitated if their linguistic forms are structured to reflect functional interrelations between their referents (i.e. if 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 training time.

The above information illustrates that the structure of work (e.g., Egan & Gomez, 1985) as well as the person-computer interface, will affect the type of skills needed as well as how difficult it might be for the individual to acquire these skills. At this stage, we know that human ability and job skills in combination affect the learning process when acquiring computer skill. Additionally, the training design must consider these factors, thereby allowing less able individuals to acquire the skills to perform well (e.g., Gattiker, 1990c). For example, handicapped individuals may require a person-computer interface which specifically adjusts for their handicap, thereby making it feasible for them to perform the required tasks using the computer.

Characteristics of Training Design for the Acquisition of Computer Skills

While an individual's abilities affect his or her capability of learning new skills, substantive complexity and autonomy-control influence the type of skills to be learnt. In combination, abilities and required job skills determine the type of training most suitable in order for an individual to acquire a skill in the shortest time possible while also achieving a satisfactory performance level. Thus, individual factors as well as job characteristics, as shown in Figures 1 and 2, interrelate with the actual delivery and design of training (see Figure 4). For instance, teaching methods may change depending upon the ability levels of participants and their age (Gattiker, 1990c). The following discussion is organized around (a) the relationship between knowledge and skill inventory of trainees, (b) learning setting, (c) teaching method and (d) duration and frequency of skills acquisition with learning outcomes/skills acquisition.

Knowledge and skill inventory. In most of the literature the reader is often not sure of the skill level of training participants. For instance, Bayman and Mayer (1988) reported a study teaching university students a computer language called Basic. Nowhere in the study did the authors explain the skills held by individuals before starting training (e.g., typing skills). Moreover, transfer-of-knowledge could have occurred if some individuals already knew a programming language (e.g., Fortran and/or Pascal). Implicit is that training participants may have had above-average ability in comparison to the population since they were university students (e.g., Butcher & Muth, 1985).

Case and Acar (1989) did a study to assess the learning of novice and expert users of a computer aided design system (CAD). Again, the authors did not report differences based on previous skills and/or knowledge/ability levels in learning performance. Theory has also suggested that positive attitudes[10] are important to computer training and learning in general (e.g., Ford & Noe, 1987; Noe 1986). Research has supported this claim to some extent (e.g., Gattiker & Hlavka, 1991).

The above, with the combination of an ever increasing heterogeneous workforce due to immigration, increasing numbers of refugees and international agreements encouraging labor movements (e.g., Common Market), make such issues important -- especially, since most current research on training and education is based on relatively homogenous groups (e.g., university students). The challenge for EUC training will be in offering courses to a heterogenous workforce. Consequently, pre-training assessment may help in providing a fit between training content and individual skill-upgrading needs and abilities.

Learning setting. While various learning settings are used to teach computer skills (cf. Table 3), comparisons of their respective feasibility for acquiring different skills have not been extensively tested. Rosenfield, Lambert and Black (1985) reported that students seated in circles engage in significantly more on-task behavior than those seated in rows or clusters. Training or classroom environments which encourage group learning or de-emphasize the use of report card grades also reduce the perceived dispersion of ability levels by pupils (MacIver, 1988). Also, co-operative learning environments increase the status of female students (Johnson, Johnson & Stanne, 1986).

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 is likely to be used. However, research using these learning settings and testing their effect upon learning performance is non-existent for all practical purposes (Burke & Day, 1986).

Insert Table 3 about here

Teaching method. As Table 3 indicates, numerous teaching methods are being used to train students and employees. For instance, Hall, Rocklin, Dansereau, Skaggs, O'Donnell, Labiotte and Young (1988) investigated individual differences in the recall of procedural and structural/functional information. The results showed that students who studied in dyads (cooperative learning) recalled significantly more than 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 held 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 formulated. 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 studying learning outcomes, the behavioral modelling approach still seemed to be the most successful training method as compared to others such as CAI, peer training and self study (Burke & Day, 1986).

Duration and frequency of skill acquisition. Literature suggests that for relatively complex tasks, more than four hours of training and skill practice is necessary to eliminate performance differences based on an individual's cognitive resources (Ackerman, 1988). Many reports on organizational and educational training, however, are based on studies of very short duration, while only a few investigations conducted in educational institutions describe experiments lasting more than a week (e.g., Gettinger, 1985; Keith, 1982).

Literature also suggests that an intermittent approach to training appears more fruitful than a continuous approach (see also Table 3). Intermittent training gives the trainee the opportunity to practice newly acquired skills (e.g., by reviewing lessons or doing assignments at one's own/preferred time and/or speed), thereby attaining a higher level of automaticity[11]. 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).

PART 3: COMPUTER SKILLS ACQUISITION: FUTURE RESEARCH CHALLENGES AND OPPORTUNITIES

What distinguishes the approach of this paper from earlier work in this area is that literature from diverse fields and disciplines was used to develop and discuss the framework as outlined in Figures 3 and 4. Such a omprehensive approach will benefit the field of EUC by advancing understanding and knowledge about the processes and variables involved in the acquisition of computer skills. In the following section research is discussed which has specifically applied portions of the framework presented in Parts 1 and 2 to training in the EUC domain. This approach will help us to identify the gaps in past EUC research when assessing the framework developed earlier in this paper.

Identifying the gaps in the EUC literature will then enable us to develop propositions to be tested in future research. Such testing is needed to determine to what extent, if any, the framework developed in Parts 1 and 2, provides a better, more consistent framework for understanding computer skill acquisition in the workplace. In the area of computer skill acquisition, the time is ripe for development and testing of a comprehensive framework, and for comparative testing of predictions derived from the model. The propositions made below are, of course, not all inclusive but limit themselves to areas where research is very scarce at the moment and, therefore, needed to advance knowledge in the training domain of EUC.

Individual Differences, Technology-Task Interface and Computer Skills Acquisition

This section reviews the literature according to Tables 1 and 2. Past research has investigated the effects of gender on learning and computer skills 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 in a competitive one during computer skills acquisition. Further, Anderson (1987) reported that high school girls performed better than boys 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 and Paulson (1987), reported on a series of studies with management students in an undergraduate university course, and concluded that students were able to transfer practice effort into higher learning performance. The data also indicated that transfer of learning from a previous computer science course had a significant effect on learning for high ability students.

Ergonomics can also affect the student's perception of a computer and his or her motivation to learn about the machine. Computers may be perceived as having certain personalities and this can 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 viewed as easier to use, happier, less expensive and more personal while the IBM PC seemed more technical, formal, expensive and professional. 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 person-computer interface.

Computer ergonomics have been shown to affect learning outcomes. For instance, the presentation of abstract information about a problem to be solved with the help of the computer reduces performance by low-ability individuals, while performance increases with the presentation of concrete information (Lamberti & Newsome, 1989). Other research indicates that if semantically specific terms are required to use certain software, difficulty in learning and remembering command vocabulary can be reduced (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 speed was somewhat reduced.

<u>Potential Limitations of Past Research</u>

Although the above review is definitely not complete, this information, together with the literature discussed earlier and also the conceptual framework outlined in Figures 1, 2, 3 and 4, reveal several weak spots in skill acquisition research, particularly as it pertains to the end-user computing domain. First, it was not possible to locate research which assessed the effect of perceptual speed ability or psychomotor ability upon learning performance. Secondly, the literature does not identify the level of complexity of the skills to be acquired during computer training. As previous research has shown (e.g., Ackerman, 1988), performing complex tasks efficiently requires more training than for performing less complex tasks.

> *Proposition 1: Perceptual speed and psychomotor abilities' effect upon computer-skill acquisition will be moderated by the level of complexity of the skills to be learnt.*

Assuming that skill is a learnt behavior (Adams, 1987), increased complexity (e.g., information processing) raises the demand put upon the perceptual speed and psychomotor abilities of the individual. For instance, an air-traffic controller at a major hub must process a substantial amount of information quickly, while using his/her psychomotor abilities to enter data into the computer and communicate with the cockpit crews in his/her sector. Acquiring these skills takes more time for lower ability individuals (cf. Kanfer & Ackerman, 1989) and lack of accurate processing and speed could result in air fatalities.

The level of task consistency and its effects on 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 automate some cognitive process and acquire the speed needed to perform the task (Ackerman, 1987).

> *Proposition 2A: Psychomotor abilities' effect upon computer-skill acquisition will be magnified by a high level of task consistency.*

> *Proposition 2B: Perceptual speed's effect upon computer-skill acquisition will be magnified by a low level of task consistency.*

The first of the above two propositions assumes that a high level of consistency requires a higher speed and accuracy in one's motor responses (e.g., 911 phone operator) than a job with low consistency (e.g., stock analyst) (Schneider, 1985). In contrast, the second proposition states that inconsistent tasks require higher levels of perceptual speed to perform at a satisfactory level. Hence, more cognitive resources are required to cope with task inconsistency.

The lack of research dealing with the person-computer interface and learning is more disturbing than other omissions. Although much research has been published about person-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, research dealing with the effect of the potential interrelationship of individual differences (e.g., expectancy) and computer ergonomics upon learning performance was not available. Research indicating that a restriction of program features helps novice learners acquiring new skills for using software is helpful (e.g., Carroll & Carrithers, 1984); however, reasons and explanations for these results grounded in theory (e.g., learning theory) must be found if we are to advance knowledge and understanding of learning processes in the EUC domain.

Another concern which must be mentioned is that past literature has usually used novice learners of computer skills when testing certain hypotheses and relationships. However, rapid change in computer hardware and software can lead to skill obsolescence for current users ("old hands") unless training which provides skills upgrading, is offered to these end-users. It is probable that task constraints and the person-computer interface can affect learning effectiveness as well as subsequent job performance (see also Tables 1 and 2) (e.g., Burke & Day, 1986; Nelson & Leonesio, 1988). Thus, the following two propositions can be put forward:

> *Proposition 3: Person-computer interface (e.g., graphics and screen contrast) will have a greater effect upon learning performance and subsequent on-the-job performance for novice learners than for experienced computer users.*
>
> *Proposition 4: Person-computer interface will have a greater effect upon older users than upon their younger counterparts (e.g., over 50*

years old versus younger individuals who graduated from college within the last 10 years).

Past studies have generally concentrated on younger subjects (less than 30 years of age), without assessing the potential effects of age on learning (with some notable exceptions, e.g., Craik & McDowd, 1987; Gist, Rosen & Schwoerer, 1988). Proposition 3 is based on the literature which suggests that the degree of transferability (e.g., previous computer use) may compensate for difficulties in the person-computer interface (see also Table 2) (Fellmann, Bräuninger Gierer & Grandjean, 1982; Gattiker & Paulson, 1987; Östberg, Shahnavaz & Stenberg, 1989). Proposition 4 is grounded in the literature which suggests that certain cognitive abilities are reduced with age (e.g., Ackerman, 1987; Craik & McDowd, 1987).

A further concern is the way in which learning is affected by the interrelationship of individual abilities, motivation and software ergonomics. This is still largely unknown and research is practically non-existent for all practical purposes. Which leads us to the next proposition:

Proposition 5: The person-computer interface (e.g., software ergonomics) effect upon learning performance is higher for below average ability individuals than for their high ability counterparts.

The above proposition is based on the theory, and previous research, which suggests that lower ability individuals are more affected simply because the more limited cognitive and attentional resources may not enable the individual to compensate for person-computer interface problems (e.g., software complexity and a highly technical manual) (Creed, Dennis & Newstead, 1988). Thus, the performance gap between high ability and lower ability individuals is widened (e.g., Gattiker, 1990c; Hativa, 1988). Such difficulties can increase the time demand upon learning for achieving satisfactory performance (Schneider, 1985; Schneider & Fisk, 1982).

The above propositions are, of course, not all encompassing but point out the major areas where additional research should be done. Specifically, these propositions should be tested in the context of continuous education efforts undertaken to advance skills held by employees. The above propositions are primarily based and derived on research which was conducted in educational settings (e.g., universities), thus, not necessarily allowing a generalization to the larger population. For instance, resistance toward new technology has become a focal point recently (e.g., big brother is watching, accidents and health concerns). As research with workers indicates, novice users differ from "old hands" in perceptions and attitudes toward further computerization of the workplace (e.g., Gattiker & Howg, 1990). Consequently, moderating variables may occur in worksettings which may be of little influence in traditional educational settings (e.g., workflow, unionization, past experience, trust between management and workers). Such variables can affect individual's attitudes toward change, training and may, therefore, affect learning performance (e.g., Gattiker & Hlavka, 1991). Unfortunately, these issues are in large part yet to be addressed by researchers.

Training Delivery and Computer Skills Acquisition

The following section reviews past research based on Table 3. Research on training and skills acquisition in end-user computing has flourished within the last decade (Hebenstreit, 1985). Some of the issues addressed in this section may be of lesser importance in a university setting, where people are assumed to be exposed to change and may take the whole thing as part of their learning experience. Nonetheless, even in this context, novices have different fears and these tend to affect the learning of end-user skills (Gattiker & Hlavka, 1991). Moreover, certain occupational groups differ in their attitudes toward computer technology (Gattiker & Nelligan, 1988), and negative experiences with "older" technologies (e.g., phone) are sometimes being repeated with computers, thereby increasing resistance (Gattiker, Gutek & Berger, 1988). All these issues can in part be investigated and hopefully answered by testing the propositions put forward above and in this section. The following sections reveal three interesting facts: (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 - therefore not allowing comparison between methods and learning outcomes.

Most research on computer training is 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. For instance, 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. Bayman and Mayer (1988) also presented data which suggest that students who learned 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 who were taught with a manual emphasizing the syntactic features of the language.

Barnard, Hammond, MacLean and Morton (1982) used intermittent training (two sessions -- two weeks apart) to teach interactive commands for text-editing software. Initial training was limited to a couple of hours. Reed (1985) used 40 minute experiments to test how the effect of computer graphics and their use might improve estimated answers to algebra work problems. Vicente and Williges (1988) 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, Lambert and Findlay (1989) provided novices with 40 minutes of training to learn a text-editor before assessing the subjects' learning performance.

Gattiker (1990a) reported on a series of studies with management students in an undergraduate university course, and 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 had a significant effect on learning for high ability students when acquiring declarative knowledge, but not procedural knowledge (cf. Ackerman, 1988).

<u>Potential Limitations in Past Research</u>

Most training is of <u>short duration</u> (up to approximately four hours) (e.g., Bayman & Mayer, 1988; Davies, Lambert & Findlay 1989). Is this sufficient time for people to acquire an understanding of the program and task requirements? Did they have enough time to improve performance, speed and accuracy through practice, or to automate some skills to reduce the cognitive resources required to perform certain tasks efficiently (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 only attained after the first three hours of training on relatively simple cognitive tasks. As the learning of 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 to a level where some degree of automaticity can be attained (cf. Ackerman & Schneider, 1985). Second, most studies have not differentiated between declarative and procedural knowledge. A particular teaching method, in combination with differences in time spent practising, might be more suitable for acquiring either type of knowledge (i.e. declarative versus procedural).

> *Proposition 6A: If an individual's declarative knowledge about basic, social and conceptual skills is deficient (e.g., functionally illiterate), training time required for satisfactory performance using the computer for doing these tasks will increase.*

> *Proposition 6B: If an individual's procedural knowledge held about basic, social and conceptual skills is deficient (e.g., how to solve a calculus problem), training time required for satisfactory performance using the computer for doing these tasks will increase.*

The above suggests that before a manager or other employee can use a decision-support system package effectively, we must ensure that he/she has the declarative knowledge required (e.g., mathematical assumptions made by the program and their implication upon the results are understood). If the necessary declarative knowledge is lacking (person was never able to understand statistics when it was taught in high school/college), substantial additional training is necessary. Furthermore, time requirements for achieving a desired level of understanding also depends upon the person's ability (see Figures 3 and 4 illustrating graphically these links).

The situation as proposed by Proposition 6B is somewhat easier to compensate for with additional training. Consequently, lack of practice may have slowed down the individual when doing a calculus problem, but some additional practice can take care of this deficiency. Propositions 6A and 6B imply a two-stage procedure, namely: (a) declarative and procedural knowledge of a desirable level (e.g., as given by job demands) must be attained first while, thereafter, (b) the computer skills needed to perform these job-related tasks using a computer can be acquired. Failure to proceed according to these two stages will ultimately hinder the individual's effective use of the technology, and decisions may be made based on data which rests on analyses which are not robust, thereby increasing the risk of failure.

Another area where more research is needed is in the potential effects of intermittent versus continuous training on computer skills acquisition. Most studies use continuous training over a short period of time. The difficulty with such studies is that they do not enable the assessment of effects on learning of such important moderating variables as motivation and time spent practising newly acquired skills (Anderson, 1987). Moreover, homework can compensate for ability differences (e.g., Keith, 1982). Another advantage of intermittent training is that individuals who have not been part of formal schooling for some time may have to get back into a study mode. Hence, continuous training may overwhelm some individuals, and accordingly, and much of the new material covered in training may not be absorbed. As suggested in the literature dealing with performance appraisals (e.g., Bernardin & Beatty, 1984), frequent feedback giver to participants through homework assignments can reinforce desirable behaviors and motivate the individual accordingly. All these important moderators can be detrimental to the effectiveness of training when using continuous training.

> *Proposition 7: If basic, social and conceptual skills are deficient (e.g., below average, functionally illiterate), learning and on-the-job performance will be significantly higher if training provided is intermittent -- assuming that absolute hours of training are equal in comparison to continuous training.*

Literature already suggests that intermittent training for acquiring computer skills can be used effectively by lower ability students to invest more time in practising newly acquired skills, thereby increasing their level of automaticity while decreasing the performance gap to high ability individuals (e.g., Gattiker, 1990c; Gattiker & Paulson, 1987). Thus, a testing of Proposition 7 may shed some further light on the computer skill acquisition process. A final concern may be that in most cases, unfortunately, one or two teaching methods are used and compared for their learning outcomes in only one learning setting (e.g., classroom or on-the-job setting). Studies that assess more than one teaching method and compare learning outcomes which evolve out of at least two different learning settings are required (cf. Lepper, 1985; Snow, 1986). A study by Czaja, Hammond, Blascovich and Swede (1989) made an attempt to study individual factors (age groups) and the design characteristics of computer skills training (i.e. on-line training, document-based training and instructor-based training). The data indicated that young learners were more successful than their older counterparts. However, no significant age by training interactions were reported.

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 skills acquisition. Hativa (1988), using a longitudinal design, reported that CAI and practice in arithmetic widened the gap between high- and low-achieving students (see also earlier section on Teaching Method for further discussion of this issue).

> *Proposition 8: If several teaching methods are used for computer skill acquisition, motor/cognitive ability limitations will be reduced, thereby positively affecting the shift of information processing from a serial to a parallel mode*[12]

The above proposition basically assumes that individual differences in learning require the use of various methods. This will help in ensuring that each individual will benefit by experiencing, sometime during the training, a method which is most helpful to his/her learning process.

Case and Acar (1989) did a study to assess the learning by novice and expert users of a computer aided design system (CAD). The study assessed the relationship of learning time and program design, as well as the effects of different software designs (e.g., menu driven versus command language) upon learning outcomes. The study assessed not only the task and person-computer interface, but also some of the design characteristics of computer skills training (computer/software ergonomics and teaching method) (see Figure 1). The data let the authors conclude that a CAD using a machining analogy, for geometric and manufacturing ideas to be expressed through familiar engineering terminology, is easy for practising designers and manufacturing engineers, as well as novice users, to learn.

> *Proposition 9: Training effectiveness for computer skill acquisition (i.e. the level of learning and the time required) can be significantly reduced, if the training integrates past experiences (e.g., lingo used is familiar to trainee) and relevance to job applications can be provided by moving from declarative (concepts) to procedural (theory) knowledge, to the application of the former to solve job-related exercises/simulations/tasks during training).*

The above implies that if the individual has an opportunity to "discover" the applicability and usefulness of newly acquired skills to his/her job during training, transfer from learning to the job will be increased (Baldwin & Ford, 1988). Finally, for propositions 8 and 9, it is likely that developmental factors, (e.g. learned views of the world and learned sex roles), interact with the training environment and thereby affect the evaluation of the situation (e.g., resistance toward technology) (cf. Gattiker & Howg, 1990; Studd & Gattiker, 1991).

PART 4: SUMMARY AND CONCLUSIONS

Extensive use of learning theory in research dealing with end-user computing issues is too new, and a systematic investigation of its application to organizational settings is too limited, for a theory about its applicability to training effectiveness in continuous education (i.e. skill upgrading or re-training) and its effects to have evolved and received general acceptance. As a result, the propositions set forth here were not derived from a generally accepted theory. Instead, they were pieced together from educational, sociological and psychological research dealing with skill acquisition, extrapolating only when it seemed reasonable.

A theory may be defined as a set of related propositions that specify relationships among variables (cf. Blalock, 1984, chap. 1). The propositions set forth in this article, relate to one another (at the very least) through possession of a common independent variable, computer skills (learning outcomes and job performance), and thus passes this definitional test of a theory. Yet more should be expected from a theory, such as a framework that integrates the propositions.

The propositions in this paper serve as building blocks for the development of a less atomistic, more conceptual theory dealing with computer skills in the workplace. Moreover, the framework presented must be subjected to review, critique, and discussion across an extended period before gaining general acceptance. However, it is important that the research be carried beyond the traditional discussions and disciplinary boundaries of these issues (Gattiker, 1991).

An important conclusion drawn from the research on learning and job skills in the workplace is that limited cross feeding and integration of research results is occurring between work in education and training, personnel psychology and ergonomics as well as in cognitive psychology. This limited cross-feeding is reflected when studying the network dependency of journals. Network dependency data suggest that most journals do not influence researchers outside their subset, thus they lack a broad interdisciplinary base, and which encourage an increasingly narrow focus. There are, however, some notable exceptions (see Salancik, 1986). More recently a study by Extejt and Smith (1990) indicates that pre-selection of journals in lists ranking them according to prestige might be biased already. Hence, ranking the importance of journals dealing with management/training issues across disciplines by using, for instance, members from the Academy of Management (e.g., Britain and USA) versus the Sociological Association (e.g., Britain, Germany, India and USA) will produce vastly different lists, reinforcing Salancik's (1986) findings that the interdisciplinary base of journals and their readers is limited in most fields. Accordingly, the narrow focus of journals is further reflected in research dealing with skill acquisition in the Eu ' domain.

One of the major difficulties in EUC training is that a definition for the term "skills" is so far not available. The one provided herein is a first step in furnishing a framework for assessing training and skill acquisition in the EUC domain. Training is strategically important as far as the up-skilling versus de-skilling debate about technology is concerned. Failing to provide adequate EUC training will increase the difficulty of finding employees with the skills required for certain positions. One outcome may very well be the de-skilling of certain types of jobs to improve the labor market pool for positions being opened.

Past findings based on high school/university students' learning of primarily basic skills must be confirmed or modified utilising participants acquiring computer skills. Using the approach proposed herein, research must be done using non-traditional learners in continuous education or organization-sponsored-type training settings to assess the viability of the propositions. A narrow focus can lead to reinvention of the wheel, rather than the advancement of our knowledge in an important area of scientific endeavor. Thus, establishing the generalizability of the theory requires its testing in various work/learning settings and countries to see if the propositions concerning underlying psychological mechanisms, skill acquisition given variations in social and cultural environments, are in fact cross-culturally valid (Gattiker, 1990c). Only such additional testing will provide us with the data needed to be able to assure adequate skill levels for an increasingly heterogenous workforce consisting of individuals with various cultural and national backgrounds, and levels of formal education.

FOOTNOTES

1) Ergonomics is a science which is concerned with the study of the functional relationships 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. The concern is primarily with physical and sensory-motor aspects of humans and not the intellectual side. Ergonomics is one aspect of the person-computer interface (see also Footnote #2).

2) The more traditional term used is "man"-computer interface which has been

replaced here with a gender neutral term. Person-computer 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, person-computer interface looks at the physical context of work (e.g., workstation design, illumination, ambient temperature, privacy and social interaction, and also visual and acoustical privacy) as well as ergonomics [e.g., ergonomics of hardware such as the visual-display terminal (VDT) and keyboard design, software ergonomics and user friendliness of technology applications]. The difference between ergonomics and person-computer interface is that while the former looks at the physical and sensory-motor aspects, person-computer interface goes much further by considering ergonomics issues in the larger context of the workflow, work design and the work environment in general as well as the individual's attentional and cognitive resources (e.g., knowledge, reasoning and information processing). Hence, successful person-computer 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) Economists use the term skill as well. However, economic literature is distinguishing between firm-specific and general-type skills. While the former type of skill is characterized by its limited transferability from a particular job and/or firm (i.e. narrow focus of training) to another job/firm, general skills are characterized by their ease of transferability to another job/employer (e.g., writing skills). Consequently, general-type skills increase the individual's opportunity to bargain for higher wages, failure to offer a competitive wage (based on external market) might increase the firm's vulnerability to poaching of such employees by competitors. The literature assumes that poaching of employees holding general skills by competitors reduces the latter's costs for training. Firm-specific skills are assumed to be acquired in situations in which the employee receives in-house or on-the-job training, while training provided by educational institutions is usually general in focus, in order to appeal to a larger audience. Interestingly, economics literature does not go beyond this rather general definition (e.g., see Becker, 1975; Barron, Black & Lowenstein, 1987; Feuer, Glick & Desai, 1987; Hashimoto, 1981 for a more extensive discussion of these issues), hence, offering little additional insight for EUC training beyond the approaches from psychology and sociology.

4) These terms differentiate between knowledge <u>about something</u> (declarative knowledge) and knowledge of <u>how to do something</u> (procedural knowledge) (Ackerman, 1987).

5) This definition also avoids the problems encountered when translating the term computer skills into other languages such as French. For example, the term skill may be translated in several ways (e.g., <u>habilité</u>, <u>competence</u>, <u>éxpertise</u> and <u>qualification</u>), each underlining certain aspects of the term (e.g., see Leplat, 1990 for a discussion of this issue), but not fully capturing it as is accomplished with the definition proposed herewith.

6) The up-skilling versus de-skilling debate deals extensively with the interrelationship of educational policies, labor market stratification and unionization with workflow and job design. How these factors may interrelate with the use of new technology and, thus, directly and indirectly impact on the job and the employee's skill level has been discussed elsewhere (e.g., Attewell, 1987; 1990; Gattiker, in press; Leontief & Duchin, 1986; Müller-Böling, 1978; Wall, Clegg, Davies, Kemp & Mueller, 1987).

7) Computer ergonomics applies to such things as workstation design, readability of screen and movement of keyboard or tilting of screen to adjust to the human's motor needs (e.g., avoid eye fatigue) (see also Footnote 1).

8) Although these differences in preferences for ambient temperatures between the

sexes may be explained by different metabolisms, haute-couture most certainly is to blame for increasing this difference beyond biological explanation by having men wear jackets while women often wear blouses. Thus, clothing makes women even more susceptible to "low" ambient temperature at work. Most interesting is the fact that from an energy conservationist perspective, ambient temperature in offices should be around 18° Celsius in winter, while cooling below 25° Celsius in summer does not appear justified from an environmentalist point of view. Unless fashion changes (e.g., men not wearing tie and jackets in summer), however, this environmentally sound objective of reducing heating in winter and cooling in summer might be hard to put into practice.

[9] 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 from the top of the mouse can be used to select certain commands and actions.

[10] An attitude is generally seen as a disposition to respond in a <u>favorable</u> or <u>unfavorable manner</u> to an object (Oskamp, 1977, pp. 2-12).

[11] 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 <u>controlled</u> processing since all cognitive or attentional resources are required by the individual to comprehend and learn the performing of an as yet unfamiliar task. Processing of two tasks occurs in serial fashion. According to Ackerman (1987) Phase 3 represents a situation in which <u>automatic</u> information processes are predominant. Phase 2 represents a combination of <u>controlled and automatic</u> 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 Schneider (1985), task performance is still sensitive to memory and resource-load effects. After extensive practice an individual will reach Phase 3, enable automatic processing when solving the problem, thereby making speed primarily dependent upon <u>motor ability</u> (e.g., typing speed).

[12] Once the individual has achieved Phase 3 (automatic processing), a shift of information processing from serial to a parallel mode is possible. Consequently, the individual may perform two job related tasks at the same time (e.g., taking a client's order over the phone and entering the information onto a computer-based order/shipping processing system).

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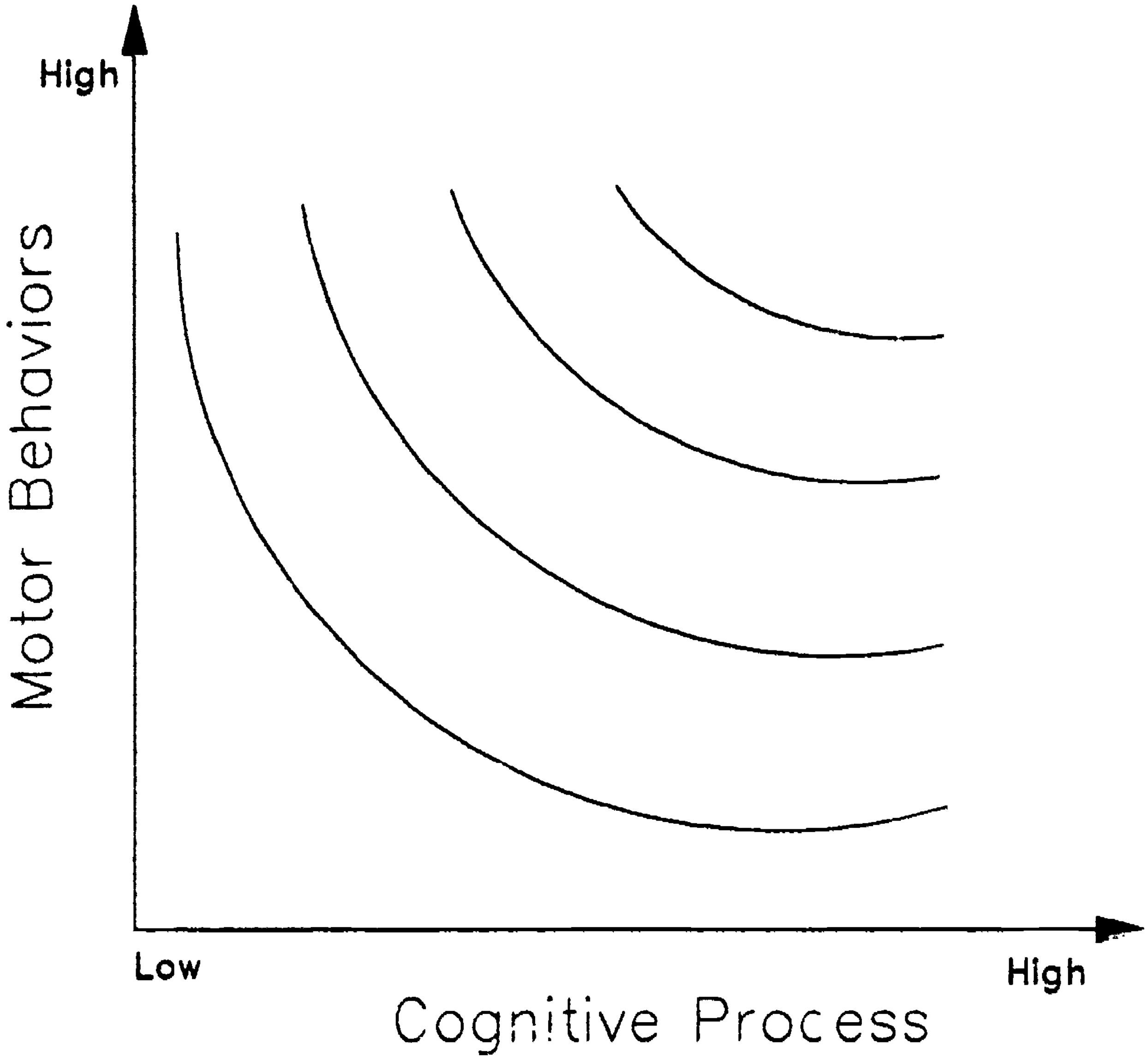

Figure 1. Human Abilities : Motor Behavioral and Cognitive Processes

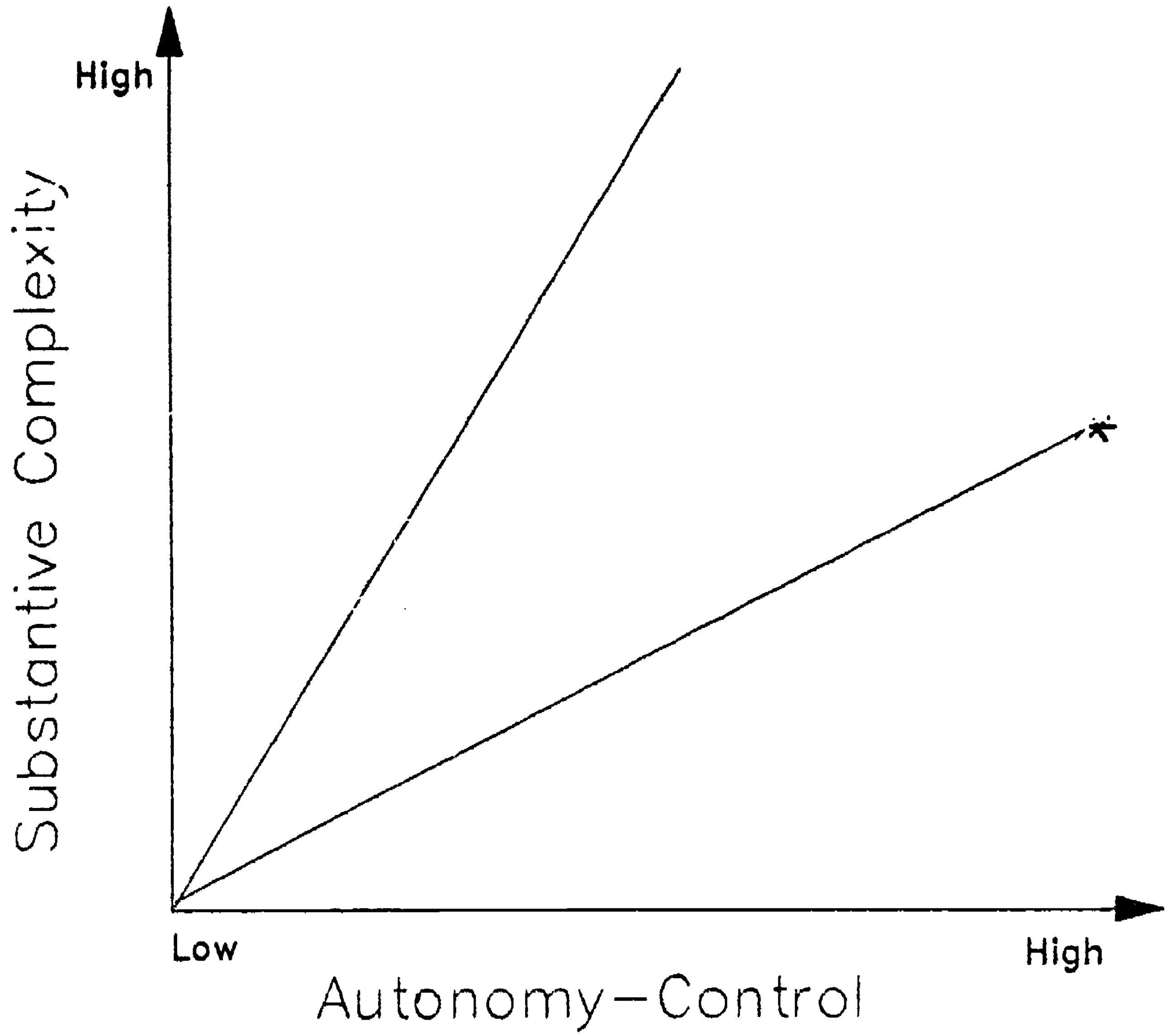

Figure 2. Job Skills : A Two-Dimensional Approach

*Research reports correlations of .50 to .70 for these two dimensions (see Spenner, 1990)

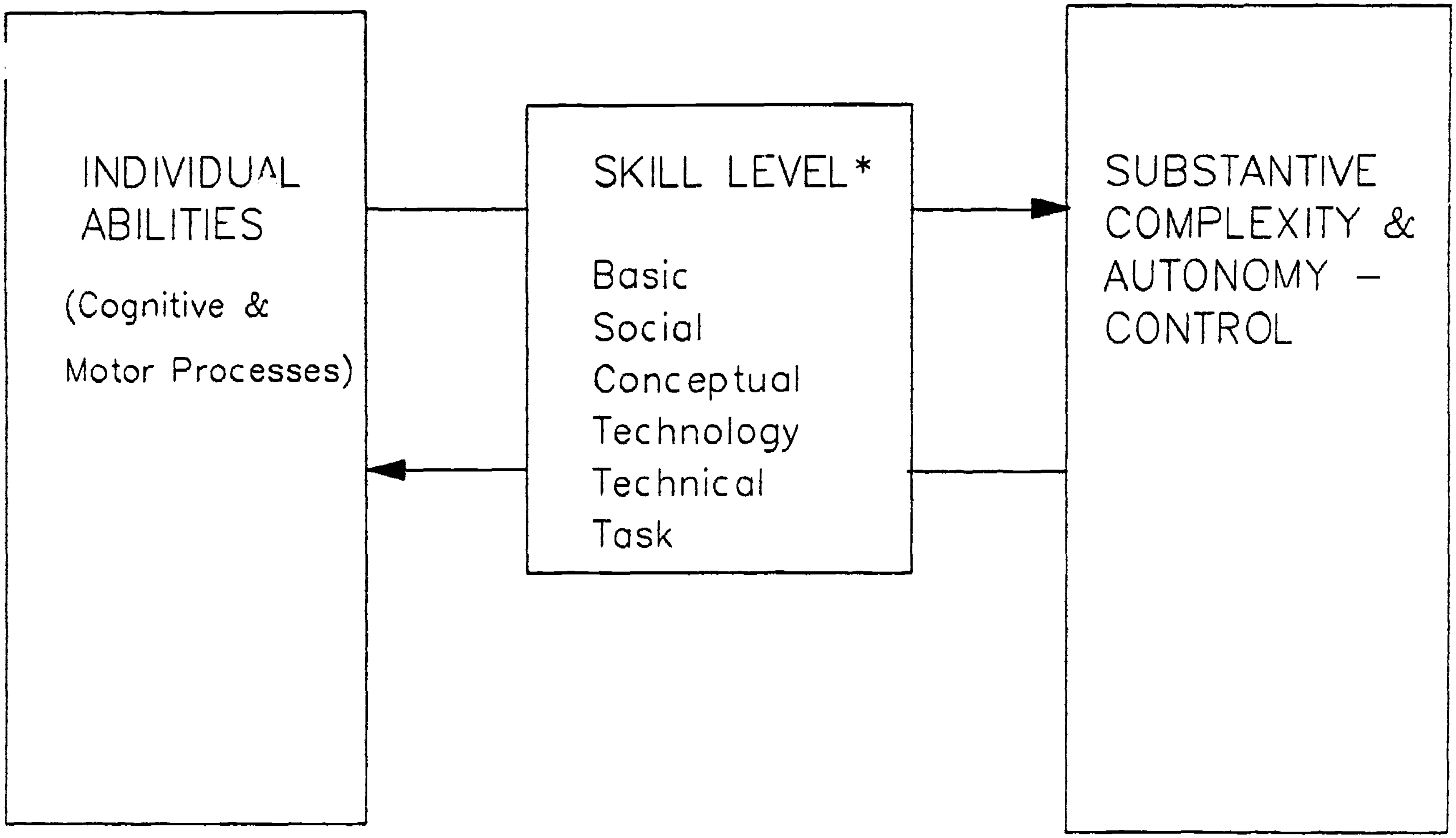

Figure 3. Reciprocal relationship between the individual's abilities, job demands and skills held.

*Skill–level means the individual's depth and breadth in a particular skill category, as well as his/her procedural and declarative knowledge about each skill category.

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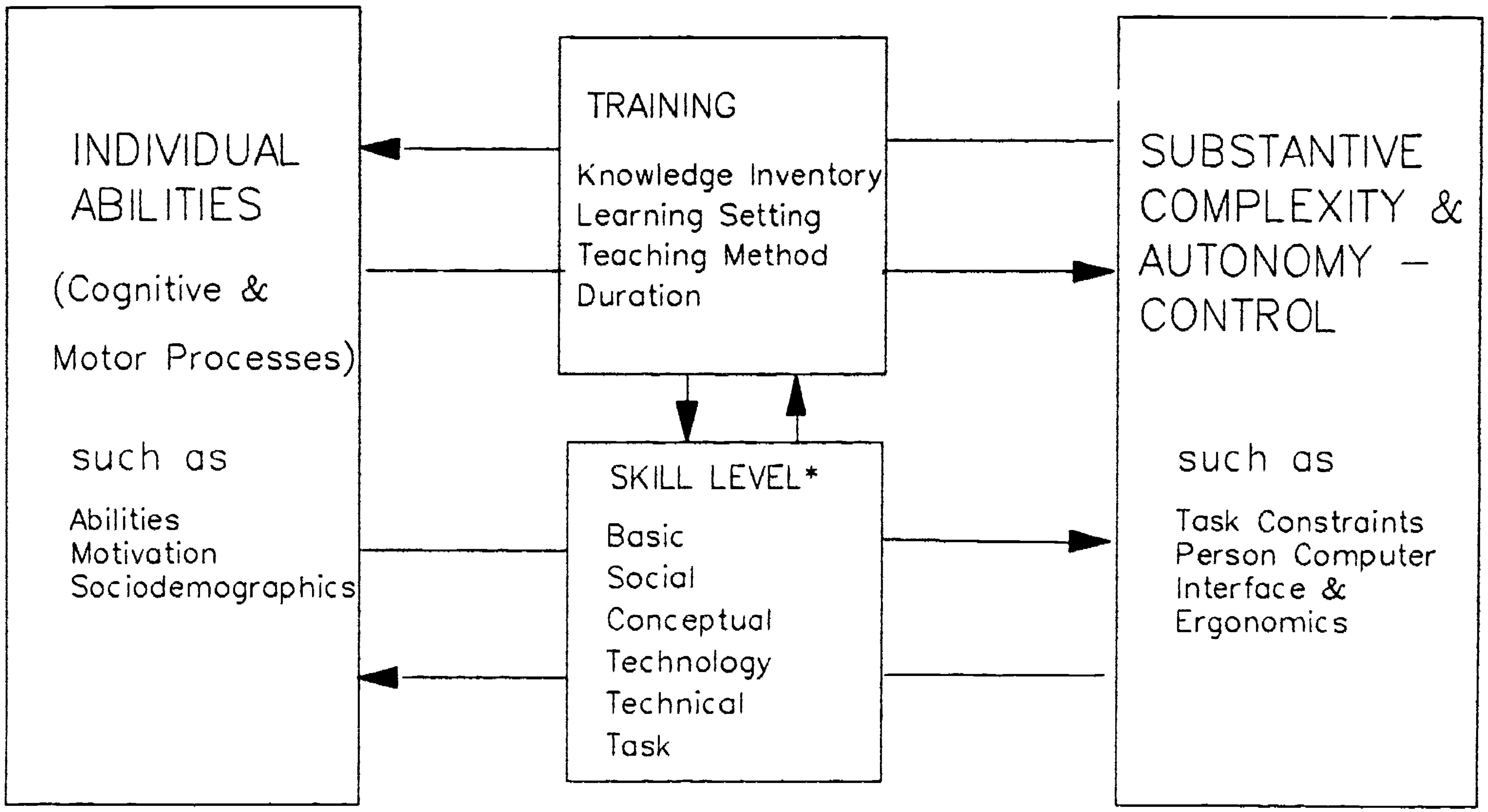

Figure 4. Reciprocal relationship between the individual's abilities, job demands and skills held as well as training design.

*Skill-level means the individual's depth and breadth in a particular skill category, as well as his/her procedural and declarative knowledge about each skill category.

Table 1

Individual Differences and Skills Acquisition

Sociodemographic Factors	Abilities and Motivation
- Age	- General Ability
- Gender	- Perceptual Speed Ability
	- Psychomotor Ability
	- Motivation and Expectancy

Table 2

Task and Person-Computer Interface and Skills Acquisition

Task Constraints	Work Environment and Person-Computer Interface
Level of:	Work Flow Job Design
- Transfer of Learning	Hardware
- Complexity	-Workstation Design
- Consistency	-Mouse and/or Keyboard Design
	-Visual-Display Terminal
	Software Design
	-Command Structure
	-Vocabulary
	Novice versus Skilled User

Table 3

Characteristics of Training Design for the Acquisition of Computer Skills

KNOWLEDGE/SKILL INVENTORY	LEARNING SETTING	TEACHING METHOD	DURATION AND FREQUENCY OF SKILLS ACQUISITION
-Skills	-Classroom	-Computer-aided Learning (CAL)	-Hours/working days of training
-Declarative/ Procedural Knowledge	-Laboratory	-Behavioral Modelling	Type of Training:
	-On-the-job	-Peer Training	-Continuous
	-Combination of the above	-Self-study	-Intermittent
		-Goal Setting	
		-Combination of the above	

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