BEHAVIORAL SCIENCES AND COMPUTING

Behavioral scientists use computers to gather library information, to collect and analyze data, and to disseminate findings to colleagues. Examples of applications in which computers are used to collect behavioral science data include: presentation of stimuli and recording of responses such as judgments and reaction times; tracking autonomic responses such as heart rate; and recording frequencies of responses in environments that are controlled and manipulated, such as the number of bar presses by an animal under different schedules of reinforcement. This article does not summarize how behavioral scientists use computers in these and other applications. Readers interested in research on the use of computers by behavioral scientists are referred to the journal *Behavior Research Methods, Instruments and Computers,* published by the Psychonomic Society.

This article presents an overview of behavioral science research on human-computer interactions. The use of high-speed digital computers in homes, schools, and the workplace has been the impetus for thousands of research studies in the behavioral sciences during the second half of the twentieth century. As computers have become an increasingly important part of daily life, more studies in the behavioral sciences have been directed at human computer use. Research continues to proliferate, in part, because rapid technological advances continue to lead to the development of new products and applications from which emerge new forms of human-computer interactions. Examples include the use of computers in the home to shop and to correspond via electronic mail over the Internet; using multimedia curriculum packages to learn in schools, conducting work and business via telecommuting; one-many or many-many synchronous and asynchronous communications; and human performance in "virtual" environments. Given the sheer quantity of empirical investigations in behavioral sciences computing research, the reader should appreciate the highly selective nature of this article. Even the reading list of current journals and books included at the end of this article is highly selective.

We present behavioral science computing research according to the following three categories: (1) antecedent-consequence effects; (2) model building; and (3) individual-social perspective. The first category, antecedent-consequent effects, asks questions such as: How does variability in human abilities, traits and prior performance affect computer use? How does use of computers affect variability in human abilities, traits, and subsequent performance? The second category, model building, consists of research on the nature of human abilities and performance using metaphors from computer science and related fields. Here, the behavioral scientist is primarily interested in understanding the nature of human beings but uses computer metaphors as a basis for describing and explaining human behavior. Model building can also start with assumptions about the nature of human beings, for example, limitations on human attention or types of motivation that serve as the basis for the development of new products and applications for human use. Here, the behavioral scientist is primarily interested in product development, but may investigate actual use. Such data may serve to modify the original assumptions about human performance, which in turn lead to refinements in the product. The third category, individual-social perspective, investigates the effects of increased access to and acceptance of computers in everyday life on human social relations. Questions addressed here are those such as: Do computers serve to isolate or connect persons to one another? What are the implications of lack of either access or acceptance of computers in modern cultures? These three categories of work in behavioral science computing are not mutually exclusive as the boundaries between any two of them are not fixed and firm.

ANTECEDENT–CONSEQUENCE RESEARCH

Personality

Research conducted since the 1970s has sought to identify what type of person was likely to use a computer, succeed in learning about computers and pursue careers that dealt with the development and testing of computer products. For example, people can be classified as being either introverted or extroverted, and these personality types have been shown to be related to many aspects of everyday life including vocational choice, performance in work groups and interpersonal functioning. Introverts are inner directed and have been characterized as reflective, quiet and socially reserved. Extroverts, on the other hand, are outer directed, sociable and generally regarded to be "people oriented." Early studies suggested that heavy computer users tended to be introverts, and programming ability, in particular, was found to be associated with introversion. Recent studies, however, reveal little or no relationship between introversion-extroversion and degree of computer use, computer anxiety, positive attitudes towards computers for pleasure or in work settings, and programming aptitude or achievement. The decision to pursue a career in computer-related fields still shows some association with introversion. Studies of undergraduate students and of individuals using computers in work settings have found that the personality characteristic of neuroticism is associated with computer use, anxiety about computers and attitudes towards computers. Neuroticism is a tendency to worry, to be moody, and to evidence negative emotions and outlooks. Neurotic individuals are likely to experience anxiety about computer use and a negative attitude about computers. Individuals who evidence a high level of neuroticism generally tend to be low users of computers as well.

Some individuals evidence such a high degree of anxiety about computer use that they have been termed "computerphobics." In extreme cases a generalized anxiety reaction to all forms of technology termed "technophobia" has been observed. Personality styles have been found to differ when individuals with such phobias are compared with those who are simply uncomfortable with computer use. Individuals with great anxiety about computers have personality characteristics of low problem-solving persistence and unwillingness to seek help from others (1). Exposure to computers and simple training in computer use has been found to decrease anxiety in many individuals who are anxious about computer use, but these methods are unlikely to benefit individuals who evidence computerphobia or very high levels of neuroticism. Intensive intervention efforts are probably necessary because the anxiety about computers is related to a personality pattern marked by anxiety in general rather than an isolated fear of computers that may in part be exacerbated by lack of experience with computers.

Gender

Gender has also often found to be an important factor in human-computer interaction. Gender differences occur in virtually every area including utilization of computers in occupational tasks, games, word-processing, and in programming, with computer use higher in males than in females. These differences may be due, in part, to differences in gender role identity, an aspect of personality that is related to but not completely determined by biological sex. Gender role identity is one's sense of self as masculine and/or feminine. Both men and women may have traits that are stereotypically viewed as masculine (assertiveness, for example) or have traits that are stereotypically viewed as feminine (nurturance, for example) or they can see themselves as possessing both masculine and feminine traits. Computer use occurs more often among men and women with a high masculine gender role identity and occurs less often among those with a high feminine gender identity (2).

Aptitudes

Intelligence or aptitude factors are also predictors of computer use. In fact, spatial ability, mathematical problem-solving skills and understanding of logic may be better than personality factors as predictors of computer use. A study of learning styles, visualization ability, and user preferences for either a direct manipulation interface (Macintosh) or command-based interface (DOS) found that learning style was not related to performance or to preferences for one system over the other, but high visualizers performed better than low visualizers on both systems. High visualizers also thought both systems were easier to use than low visualizers (3). High visualization ability is often related to spatial and mathematical ability, which, in turn has been related to computer use, positive attitudes about computers, and educational achievement in computer courses.

Others have found that the amount of prior experience with computers, like cognitive abilities, is a better predictor of attitudes about computers than personality characteristics. One study found that game-playing, word processing, and home computer use as well as knowledge of programming and of a computer language were better predictors of attitudes toward computers than personality factors (4). Student experience with computers and student gender, but not other personal characteristics, have been found to relate to computer attitudes and achievement in courses. It is not clear, however, if people who had more positive attitudes toward computers were therefore more likely to use computers or if human–computer interaction led to improved attitudes. Training studies with people who have had few computer experiences or negative views of computers reveal that certain types of exposure to computers can improve attitudes and can lead to increased computer use. This suggests that experiential factors are important and may override any differences in personality.

Overall, studies of personality factors and computer use suggest that some personality factors are associated with use. Neuroticism is negatively related, and a masculine gender role identity is positively related to computer use. However, experience with computers and cognitive factors such as spatial ability and mathematical skill appear to be more salient factors than personality factors per se. It is possible that as computers have become part of the daily life of more diverse groups of people, those personality factors that differentiate people from one another on the basis of styles of interaction, such as introversion-extroversion, have become less salient in relation to computer use. Instead, those individuals who have abilities in areas relevant to computer skills, such as spatial visualization abilities, and those who have acquired practical skills through a greater amount of experience with computers, have generally been found to evidence greater use and more positive views of computers. Several researchers have suggested that attitudes may play an intermediary role in computer use, facilitating experiences with computers, which in turn enhances knowledge and skills and the likelihood of increased use. Some have suggested that attitudes are especially important in relation to user applications that require little or no special computing skills while cognitive abilities and practical skills may play a more important role in determining computer activities such as programming and design.

Attitudes

Attitudes about self-use of computers and attitudes about the impact of computers on society have each been investigated. Research on attitudes about self-use and comfort level with computers presumes that cognitive, affective, and behavioral components of an attitude are each implicated in a person's reaction to computers. That is, the person may believe that computers will hinder or enhance performance on some task or job (a cognitive component), the person may enjoy computer use or may experience anxiety (affective components), and the individual may approach or avoid computer experiences (behavioral component). In each case, a person's attitude about him- or herself in interaction with computers is the focus of the analysis.

Attitudes with respect to the impact of computers on society may be positive, negative, neutral, or mixed. Some people believe that computers are dehumanizing, reduce human–human interaction, and pose a threat to society. Others see computers as liberating and enhancing the development of humans within society. These attitudes about computers and society can influence the individual's own behavior with computers, but they also have potential influence on individuals' views of computer use by others and their attitudes toward technological change in a variety of settings.

Numerous studies have shown that anxiety about using computers is negatively related to amount and confidence in human-computer interaction. For example, people who show anxiety as a general personality trait evidence more computer use anxiety. Males have less anxiety about using computers than females, and less experience with computers is related to computer anxiety (5a). In addition, anxiety about mathematics and a belief that computers have a negative influence on society are related to computer anxiety. Thus, both types of attitudes—attitudes about one's own computer use and attitudes about the impact of computers on society—each contribute to computer anxieties (5).

With training, adult students' attitudes about computers become more positive. That is, attitudes about one's own interaction with computers and attitudes about the influence of computers on society at large generally become more positive as a result of instruction through computer courses in educational settings and as a result of specific training in a variety of work settings. Figure 1 presents a general model of individual differences in computer use. The model indicates that attitudes can affect computer use by influencing values and expectantions. The model also indicates that computer use can influence attitude.

Gender. The effects of training on attitudes has been found to vary by gender. In general, people become less anxious about computer use over the course of training, but in some cases, women become more anxious (6). This increase in anxiety may occur even though women report a concomitant increase in a sense of enjoyment with computers as training progressed. With training, both men and women have more positive social attitudes toward computers and perceive com-

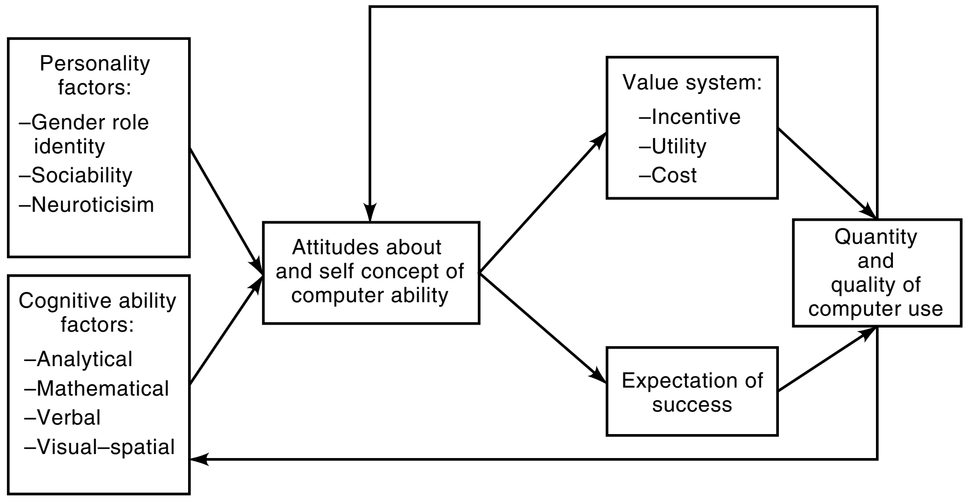

Figure 1. General model of differences in computer use.

puters to be more like a human and less like a machine; however, women do not necessarily also increase in positive attitudes as far as self-use is concerned.

Gender differences in students' attitudes toward computer use appear relatively early, during the elementary school years, and persist into adulthood. Male students have more positive attitudes than female students and also express greater interest in computers and greater confidence in their own abilities and view computers as having greater utility in society than females at nearly every age level (7–9). One study revealed a moderate difference between males and females in the area of personal anxiety about using computers, with women displaying greater levels than men. Women also held more negative views than men about the influence of computers on society. The findings of this study suggest that gender differences in computer-related behavior are due in large part to differences in anxiety. When anxiety about computers was controlled, there were few differences between males and females in computer behavior. Anxiety mediates gender differences in computer-related behavior (7).

Other studies confirm that gender differences in computer behavior appear to be due to attitudinal and experiential factors. Compared with men, women report greater anxiety about computer use, lower confidence about their ability to use the computer, and lower levels of liking computer work (8). However, when investigators control the degree to which tasks are viewed as masculine or feminine and/or control differences in prior experiences with computers, gender differences in attitudes are no longer significant (9).

Still other studies suggest that gender differences in attitudes toward computers may vary with the nature of the task. In one study, college students performed simple computer tasks, more complex word processing tasks, and complex tasks requiring the use of spreadsheet software. Men and women did not differ in attitudes following the simple tasks. However, the men reported a greater sense of self-efficacy (such as feelings of effective problem-solving and control) than the women after completing the complex tasks (10). Such findings suggest that anxiety and lack of confidence affect women more than men in the area of computer use. It is not yet clear what aspects of training are effective in changing attitudes for both women and men.

To summarize the state of information on attitudes about computer use thus far, results suggest that attitudes about one's personal computer use are related to a personal anxiety about computer use as well as to math anxiety. These relationships are more likely to occur in women than in men. However, when women have more computer experiences the relationship between anxiety and computer use is diminished and the gender difference is often not observed. In addition, some studies suggest that it is not the gender of the computer users per se that is salient in this regard but their sense of themselves as masculine or feminine. Finally, individuals who hold negative attitudes about the impact of computers on society are less likely to use computers, and such beliefs are held more often or more strongly by women than by men. As a result there appear to be several attitudinal factors involved in computer use, including math anxiety, feelings of self-efficacy and confidence, personal enjoyment and positive views of the usefulness of computers for society. Gender differences that increase the likelihood of males using computers have been observed in each of these areas, although both experience and gender role identity appear to be factors that diminish such differences.

Work Place

Computers are used in a variety of ways in organizations, and computing attitudes and skills can affect both the daily tasks that must be performed in a routine manner and the ability of companies to remain efficient and competitive. The degree of success of computer systems in the work place is often attributed to the attitudes of the employees who are end users of applications such as spreadsheets, database management, data analysis, and graphics (11). Much of the computer use that occurs in the work place is conducted by people who are not computer specialists but rely on end-user skills. That is, human–computer interaction in the work place often occurs when the worker finds a software application that is easy to use, thus it is implemented and the worker becomes a more skilled user as a result. Most research on the attitudes of employees toward computers in the work place reveal that computers are seen as having a positive effect on their jobs, making their jobs more interesting, and/or increasing job effectiveness. On the other hand, employees also report negative attitudes. Individuals sometimes report that computers increase job complexity instead of increasing effectiveness. They also have negative attitudes about the necessity for additional training and refer to a reduction in their feelings of competence. These mixed feelings may be related to employees' job satisfaction attitudes. When confusion and frustration about computers increase, job satisfaction decreases. The negative feelings about their own ability to use computers effectively leads employees to express greater dissatisfaction with the job as a whole (12).

Work-related computer problems can increase stress. When computer problems increase, so does computer use. That is, when there are problems with computer systems (e.g., down time, difficulties with access, lack of familiarity with software, etc.), individuals spend more of their work time using the computer, which often results in an increase of overall work time as well. This also results in a perception of increased work load and pressure and less feeling of control over the job. The increases in perceived work load and pressure and decline in job control are experienced as work stress associated with computers. In these situations the computer can be viewed as a detrimental force in the work place even when users have a generally positive attitude toward computers (13).

There is some indication that individuals react differently to problems with computers, and this too plays a role in their view of the utility of computers on the job. Staufer (14) found that attitudes toward computer use affected employees' reaction to technological changes in the workplace. Older staff who indicated that they felt threatened by computers tended to complain more about time pressures and health-related issues related to computer use, while same-age peers who viewed computers more neutrally or positively reported few problems or increased information-seeking activities.

Individuals' perceptions of the usefulness of computers for improving their own job performance is the best predictor of whether or not they intend to use computers in the work place. Davis, Bagozzi, and Warshaw (15) conducted a series of studies of graduate business students' intentions to utilize computers for several different aspects of work, such as word processing and business graphics, in relation to attitudes about computer use. They found that two attitudes, namely, degree of enjoyment with computer use and perceptions of usefulness, were related to intentions about computer use on the job. The perception that computers would improve their job performance was by far the strongest predictor of anticipated computer use.

Differences in computer anxiety and negative attitudes about the social impact of computers were more likely to occur in some occupations than in others. Individuals in professional and managerial positions generally evidence more positive attitudes toward computers. As was the case with attitudes about computer use in general, low levels of previous experience with computers and a poor sense of self-efficacy are related to negative attitudes about the impact of computers on the work place.

Other research has revealed that particular aspects of some jobs may influence individuals' attitudes about the impact of computers on jobs, and these findings may account to some degree for the observed occupational differences in attitudes about computers in the work place. Medcof (16) found that the relative amounts of computing and noncomputing tasks, the job characteristics (such as skill variety, level of significance of assigned tasks, and autonomy) and the cognitive demand (e.g., task complexity) of the computing tasks interact with one another to influence attitudes toward computer use. When job characteristics are low and the computing components of the job also have low cognitive demand on the user (as in the case of data entry in a clerical job), attitudes toward computer use are negative, and the job is viewed as increasingly negative as the proportion of time spent on the low cognitive demand task increases. If a larger proportion of the work time is spent on a high cognitive demand task involving computer use, attitudes toward computer use and toward the job itself will be more positive. That is, people who hold job positions that are cognitively challenging have more positive attitudes toward computers on the job, and when the job position is less cognitively demanding, individuals will show positive attitudes toward computers when they are faced with more complex tasks. People hold more positive views about the use of computers in the work place when complex and demanding job requirements are involved but hold more negative views when jobs have low cognitive demand.

Medcof's findings suggest that under some conditions job quality is reduced when computers are used to fulfill assigned tasks, although such job degradation can be minimized or avoided. Specifically, when jobs involve the use of computers for tasks that have low levels of cognitive challenge and require a narrow range of skills, little autonomy, and little opportunity for interaction with others, attitudes toward computer use and toward the job are negative. But varying types of noncomputing tasks within the job (increased autonomy or social interaction in noncomputing tasks, for example) reduces the negative impact; inclusion of more challenging cognitive tasks as part of the computing assignment of the job is especially effective in reducing negative views of computer use. The attitudes about computers in the work place therefore depend upon the relative degree of computer use in the entire job, the cognitive challenge involved in that use, and the type of noncomputing activities.

Older workers tend to use computers in work place less often than younger workers, and researchers have found that attitudes may be implicated in this difference. Both age and seniority of employees are important factors related to attitudes about computers in the work place. Negative attitudes toward computer use and computer anxiety are better predictors of computer use than age. Older workers with greater seniority in companies have more negative attitudes than younger workers or workers who are newer to their departments (17).

MODEL BUILDING

Cognitive Processes

Modifications in theories of human behavior have been both the cause and effect of research in behavioral science computing during the second half of this century. A "cognitive" revolution in psychology occurred during the 1950s and 1960s, in which the human mind became the focus of study. A general approach called information processing became dominant in the behavioral sciences during this time period. Attempts to model the flow of information from input-stimulation through output-behavior have included considerations of human attention, perception, cognition, and memory. In addition, human emotional reactions and motivation are included in some models of human behavior from an information processing perspective. This general approach has become a standard model that is still in wide use. More recent theoretical developments include a focus on the social and constructive aspects of human cognition and behavior. From this perspective, human cognition is viewed as socially situated, collaborative, and jointly constructed. Although these recent developments have coincided with shifts from standalone workstations to computers that are networked and use various forms of groupware, it would be erroneous to attribute these changes in theoretical models and explanation as being due to changes in available technology. Instead, many of today's behavioral scientists base their theories on approaches developed by early twentieth century scholars such as Piaget and Vygotsky. The shift in views of human learning from knowledge transfer to knowledge co-construction is evident in the evolution of products to support learning, such as from computer-assisted instruction (CAI) to intelligent tutoring systems (ITS) to learning from hypertext, to computer-supported collaborative learning. To benefit from this evolution, users need the motivation and capacity to be more actively in charge of their own learning.

Human Factors

Human factors (also called ergonomics) is a branch of the behavioral sciences that attempts to optimize human performance in the context of a system that has been designed to achieve an objective or purpose. A general model of human performance includes the human, the activity being performed, and the context of occurrence (18). To study the performance of systems such as human–computer interactions, human factors researchers take general goals and divide them into tasks, which in turn can be further divided into separate acts. Human factors researchers also have investigated such matters as optimal workstation design (e.g., to minimize soft tissue and joint disorders); the perceptual and cognitive processes involved in using software; computer access for persons with disabilities such as visual impairments; and characteristics of textual displays that influence reading comprehension. A human-factors analysis of human learning from hypertext is presented next to illustrate this general approach.

Learning from Hypertext. Hypertext is a method of creating and accessing nonlinear text. Information in hypertext is organized as a network of linked nodes. The nodes are self-contained paragraphs of text that may contain "hot spots," which are essential words that refer to other nodes. The hot spot links can be based on different types of relations that may exist between text paragraphs, such as background information, examples, further explanations, and so forth. Development of effective hypertext systems has required user testing. For example, the Superbook project at Bellcore required modifications in original and subsequent designs before improvements over traditional text presentations were observed (19). The general principle is that improvements to the system, considered apart from its interaction with actual users, has limitations. The technology should be thought of as a supportive component of the learning environment with efforts made to ensure usability from the learner's perspective. Dillon (19) has recently developed a framework of reader-document interaction that designers can use to meet this objective. The framework is intended to be an approximate representation of cognition and behavior central to reading and information processing, and it consists of four interactive elements: (1) a task model that deals with the user's needs and uses for the material; (2) an information model that provides a model of the information space; (3) a set of manipulation skills and facilities that support physical use of the materials; and (4) a standard reading processor that represents the cognitive and perceptual processing involved in reading words and sentences. This model predicts that the users' acts of reading will vary with their needs and knowledge of the structure of the environment that contains textual information, in addition to their general ability to "read" (i.e., acquire a representation that approximates the author's intention via perceptual and cognitive processes). Research comparing learning from hypertext versus traditional linear text has not yielded a consistent pattern of results. In some instances, learning from hypertext is better, worse, or no different from learning from traditional text (20,21). Models such as Dillon's may enable designers to increase the yield from hypertext versus traditional text environments.

INDIVIDUAL–SOCIAL PERSPECTIVE

In a previous section we presented an overview of research on gender differences, attitudes toward the impact of computers on society, and the use of computers in the workplace. Each of these issues relates to the effects of computers on human social relations. Kling (22) lists these additional social controversies about the computerization of society: class divisions in society; human safety and critical computer systems; democratization; the structure of labor markets; health; education; military security; computer literacy; and privacy and encryption. These controversies have yet to be resolved and are still being studied by behavioral scientists. Finally, we present a brief summary of an area in which computers are being used to connect people to each other. Another potential area, computer-supported collaborative learning, is somewhat beyond the scope of this article but is included in our reading list.

Computer-Mediated Communication

Studies of human–computer interactions also include using computers as a tool to communicate with other persons. There are a variety of systems that enable people to communicate with each other by using computers and networks. Computer-mediated communication (CMC) is a broad term that covers forms of communication including: bulletin boards; computer conferencing; discussion lists; electronic mail; and Internet relay chats. In comparison with face-to-face communication, CMC has fewer social and nonverbal cues but supports both synchronous and asynchronous interactions among multiple participants. The reduction in social and nonverbal cues has been found to be a negative aspect to CMC that is reduced with experience. As users adapt to the medium and create means of improving communication and become more adept at using linguistic cues, differences between CMC and face-to-face communication may be eliminated (23). Social norms and conventions within groups serve to reduce individual variability across formats rendering CMC similar to face-to-face communication, especially in established organizations. For example, messages from superiors receive more attention than messages from co-workers or from subordinates. Research on learning in the workplace and in educational institutions has examined CMC ability to support the transfer of knowledge (an "instructional" perspective) and the social, co-construction of knowledge (a "conversational" perspective) (24).

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BEHAVIORAL SYNTHESIS. See HIGH LEVEL SYNTHESIS.