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Computer Use in the Scientific Office

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ABSTRACT

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Over the past two decades computers in research and development organizations have become a complex and integral part of the work process. Yet to date only a handful of systematic investigations have addressed issues involving scientists' or other professionals' use of computers, and very little is known about factors influencing use (Bikson and Gutek, 1983; Blacker and Brown, 1986; Collopy, 1988; Gasser, 1986; Helander, 1985; Nickolson, 1985; Pope, 1985). As a result, this research was designed to address four objectives. The first was to develop and evaluate a descriptive model of variables influencing scientists' computer use. The second objective was to explore the inter-relationships among model variables, and the third was to develop a linear predictive model of use. As a prelude to these objectives, a fourth objective involved development of reliable and valid variable measures, including measures of computer use. Study participants were 104 research scientists from the IBM T. J. Watson Research Center.

Identification and operationalization of model variables resulted in eight reliable and valid measures for the assessment of use-variable relationships. There were three individual difference variables (capability with computers, perceived impact, satisfaction

with current tools), two nature of work measures (professions, work activity cluster membership), and three organizational environment variables (importance of computer literacy and skills to management, importance of computer literacy and skills to colleagues, and support system size). Six of these variables proved to be significantly related to participants' computer use, and they fell into three distinct groups or tiers based on their inter-relationships. A linear combination of profession and cluster membership accounted for 58 percent of the variance in scientists' computer use.

Overall, study results indicate that individual scientists' computer use, and by extension organizational computer use, is highly predictable based on scores from a limited set of variables. Study results suggest a three tiered network of variables influencing scientists' computer use, where tiers reflect causal priorities. Considerable research is needed to further delineate this network.

Acknowledgements

This work could not have been completed without contributions of Bucky Pope, Frank Elio, and Dr. Donald D. Davis. This work has its roots in the work and ideas of Bucky Pope, who gave an "unproven" graduate student the opportunity to conceive and conduct this project, and to begin a professional career. It is the author's hope that Bucky's spirit is reflected in these pages. Just as Bucky was the spirit behind this work Frank Elio was the friend and guide, teaching me "the organizational ropes" and then showing tremendous patience and understanding during the completion of the work. Finally, I would like to thank Don Davis for managing to strike the appropriate balance between providing guidance and allowing the author the freedom to follow his own path.

There were a number of other people who contributed to the completion of this research project. Members of my work group, including Dave Potter, Andy Demaio, and Robert Delmonico were invaluable as colleagues, advisors, and friends. My loving wife JoAnn willingly accepted three household moves and a husband who, for several years, seemed to always be busy. Finally, Dr. Glynn Coates and Dr Robert McIntyre contributed their advice and comments, and Mic Fedorko his time and friendship.

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INTRODUCTION

A National Science Foundation panel was recently commissioned to assess the role of and the need for computers among scientists (McCormick, DeFanti, and Brown, 1987; Salzman and VonNewmann, 1987). The panel concluded that computers are emerging to play as important a role in science as theory and experimentation. As we enter the 1990s, computers in research and development have become an established and vital part of the work environment. However, as the technology has moved from an abstract invention to a complex and integral part of the work process requiring considerable support and resources, many research organization managers and support staff have reported that systems are underutilized by scientists, and that computers are not contributing to scientists' productivity as much as expected.

The growth in the role and importance of computers for scientists, and the related perceptions of underutilization, reflect a phenomenon occurring in many professional fields. The 1980s saw a rapid growth in the development and adoption of computer hardware and software to support and enhance nearly all types of white collar work (Frenkel, 1988; McCormick, DeFanti, and Brown, 1987; Salzman and VonNeumann, 1987). In only a few short years many professionals who previously communicated via paper and through secretaries, kept records and accounts manually, and used typewriters for document preparation now do all three with a computer. In addition, for many professionals, computer technology is increasingly employed as an aid in decision making, problem solving, and other core tasks central to their work. Yet numerous authors have reported a failure to realize expected benefits from computer investments (e.g., Bikson, Gutek, and Mankin, 1981; Majckrzak, Collins, and Mandeville, 1986; Stewart, 1985; Wessel, 1988).

The roots of this problem can be in large part traced to the widespread adoption of these tools and associated high expectations for their widespread use despite little understanding and no theory to explain how computers could support scientists' or other professionals' work activities (Collopy, 1988; Johansson, 1987). To date, only a handful of systematic investigations have addressed issues involving scientists' or other professionals' use of computers, and very little is known about factors influencing use (Bikson and Gutek, 1983; Blacker and Brown, 1986; Collopy, 1988; Gasser, 1986; Helander, 1985; Nickolson, 1985; Pope, 1985). As a result, most organizations employ a technology-driven, laissez-faire computer management style in which users receive little systematic information about what constitutes good computer use. The user is given minimal general training and a brief learning period to discover how to absorb these tools into a productive work routine. (Bikson, Gutek, and Mankin, 1981; Blacker and Brown, 1986; Collopy, 1988; Gerrity and Rockart, 1986). Managers and systems staff develop and apply implicit or explicit criteria for the evaluation of productivity improvements or cost savings with little understanding of the determinants of scientists' computer use. Likewise, they develop support systems with an incomplete understanding of user needs. Not surprisingly, the result is typically disappointing reports arising from rather naive technology-driven expectations of high, uniform use and support systems that do little to improve use. The current research has been undertaken to contribute to the understanding of factors influencing scientists' computer use in order to permit the development of more accurate expectations of individual scientists' use and more effective computer support systems.

Models of Computer Use

Both research and experience indicates that computer use varies widely across individuals within organizations (Bikson and Gutek, 1983; Pope, 1985). However, no models or theories are yet available that explain or predict individual computer use at work (for scientists or other professions). The primary objective of this research was to construct an initial descriptive model of factors determining scientists' computer use, and to test and revise the resulting model (Collopy, 1988). In order to build this model, first, models in related research areas were reviewed for their applicability to the prediction of computer use in the scientific office; second, a literature review was conducted to identify variables previously suggested as potential use-determinants; and finally, based on available evidence, variables were selected and used to construct a testable model.

Related Models

While no models were found describing or predicting computer use among scientists or other professions, a few models from other areas of investigation were found to be somewhat related to this research concern. Most directly related to the present research are models predicting or describing the process of successful implementation of computer technologies in the workplace (e.g., Davis, 1986; Endsley, 1985). These models focus on various sets of variables and their relationships to successful technology implementation. These models typically do not focus on the "routinization" or "institutionalization" of a technology, where it is judged to be integrated into the workplace. They do not provide for the description or prediction of use once a technology is a routine part of the work environment. The current research effort explores computer use following routinization. Many of the variables influencing successful implementation may prove to influence routine use also. This study attempts to discover whether characteristics of the work place associated with the implementation of technical innovations are also related to their routine use.

Two other sets of models address relationships somewhat related to the current research. Specifically, models attempting to show how general classes of variables are related to effective organizational information systems (e.g., Zmud, 1979) and models addressing the general role or function of advanced technologies in organizations (e.g., Porras and Hoffer, 1986) are likewise concerned with effective organizational computer use. However, these models lack the specificity necessary for the description or prediction of individual scientists' computer use.

Variables in the Literature

With little direction provided by previous models or theories for the construction of a descriptive model of scientists' computer use, a literature review was conducted to identify potential use-determinants. Variables identified from this review are listed in Table 1 and are divided into the following categories: (a) Technology-specific variables; (b) Individual difference variables; (c) Nature of work variables; and (d) Organizational variables.

The diversity of the literature reviewed reflects in part the eclectic nature of this research area. Research was drawn from the fields of management information systems, industrial/organizational psychology, human factors/ergonomics, industrial engineering, computer science, and management. The element common to all studies was a concern for computer use or variables related to use. Although most of the literature reviewed addressed use as a dependent variable, either theoretically or empirically, there were a number of studies in which use was treated as an independent variable and still others that did not address use in terms of independent-dependent variable relationships. This literature can be loosely categorized into the following five topic areas: (1) the implementation of computer technologies, (2) the design and development of computer products, (3) computer user individual differences, (4) the description of computer use, and (5) the support or training of computer users. The first four categories are similar to those used by Trice and Treacy (1988) in their review of utilization as a dependent variable in management

Table 1

Variables identified as potential determinants of computer use

Technology-Specific Variables
- Ease of use
- Technology design (e.g., keyboard layout, processing capacity)
- Associated documentation

Individual Difference Variables
- Attitude toward computer use
- Personality or personality variables
- Work style
- Cognitive style
- Problem solving style
- Technostress or technophobia
- Individual demographic characteristics
- Interest in computers
- Computer experience
- Computer literacy
- Satisfaction with current computer tools for accomplishing work
- Expected impact of computer use

Nature of Work Variables
- Job requirements (e.g., work activities, work priorities)
- Support system characteristics

Macro-Organizational Variables
- Organization size
- Organization structure
- Computer support system characteristics
- Technology champions
- Critical user mass
- Social norms or expectations
- Management norms or expectations
- Management style

information system research. Each of these categories is briefly reviewed in next several sections of this report, with the Table 1 variables derived from each category noted.

Implementation of computer technologies. Research addressing the implementation of computer technologies represents perhaps the most developed body of literature bearing upon the current study. As discussed, implementation research has been concerned broadly with the individual and organizational adaptation of advanced technologies, focusing on that period of time ranging from planning for new technologies up to the point where those technologies have become a "routine" part of the work process (e.g., Bikson, Gutek, and Mankin, 1981; Davis, 1986; Endsley, 1985; Olson and Lucas, 1982; Tornatzky, 1985). These studies have focused to a great extent on the relationship between successful adoption, usually measured in terms of amount of system use, and numerous implementation process and individual difference variables. Variables suggested by this body of literature as potential determinants of routine use include: attitude toward computer use, technostress, computer experience, technology champions, critical user mass, social norms, organizational size and structure, and management norms and style.

Design and development of computer products. Numerous laboratory-based studies, largely in the human factors/ergonomics area, have addressed the effects of specific computer system characteristics on the ease of system use and user satisfaction. These studies have traditionally been concerned with the development of computer products, most often focusing on the software and hardware interfaces between computer systems and computer users (e.g., Akin and Radha Rao, 1985; Carroll, 1987; Miller, 1988). Variables suggested by these studies (e.g., Ross, 1987; Cohill and Williges, 1985; Helander, 1985) to be related to computer use include: computer experience, satisfaction with computer tools, and support system characteristics.

Computer user individual differences. A wide variety of publications have examined relationships between user characteristics and various aspects of computer use. Unfortunately, there has been little consistency across studies in operational definitions of variables, research methods, issues, or subject populations. For example, a random sample of topics might include: (a) the relationship between anxiety and system response time (Guynes, 1988); (b) attitudes toward computers and their use (Anderson, Jay, Schweer, and Anderson, 1985); (c) personality and learning FORTRAN (Kagan and Douthat, 1985); and (d) the relationship between problem solving ability and programming skill (Nowaczyk, 1984). Overall, the following variables were identified from this literature as possible determinants of computer use: attitude toward computer use, various personality characteristics, work style, cognitive style, problem solving style, various demographic characteristics, interest in computers, computer literacy, computer experience, satisfaction with current computer tools, and expected impact of computer use.

The description of computer use. A few studies were found largely concerned with the description of computer use, including both the amount of use and its distribution across various computer tasks (viz., patterns of use; Bikson and Gutek, 1983; Collopy, 1988; Kublanow, Durand, and Floyd, 1985; Lee, 1986; Pope, 1985; Stubler, Charipper, and Hanes, 1987). The findings of several of these studies suggested relationships between computer use and job requirements, with job requirements typically operationally defined as professions or categories of computer activities (e.g., electronic communications, document editing).

Support or training of computer users. Computer support or training articles were the least common of the five categories of literature reviewed. Of the studies found, most were concerned with "micro" issues such as the design of specific software help systems or documentation (e.g., Cohill and Williges, 1985; Ross, 1987). These studies generally assume relationships between support system characteristics and computer use. Only Lee's (1986) work investigated "macro" computer support systems in a fashion relevant to this research (i.e., involving organizational support system characteristics such as support network size, types of support). Among Lee's findings were that a small set of co-workers he termed "lead users" were the most popular and effective sources of computer support, and organizational support sources were used less than expected. Lee's work suggests support system size and characteristics as potential determinants of computer use.

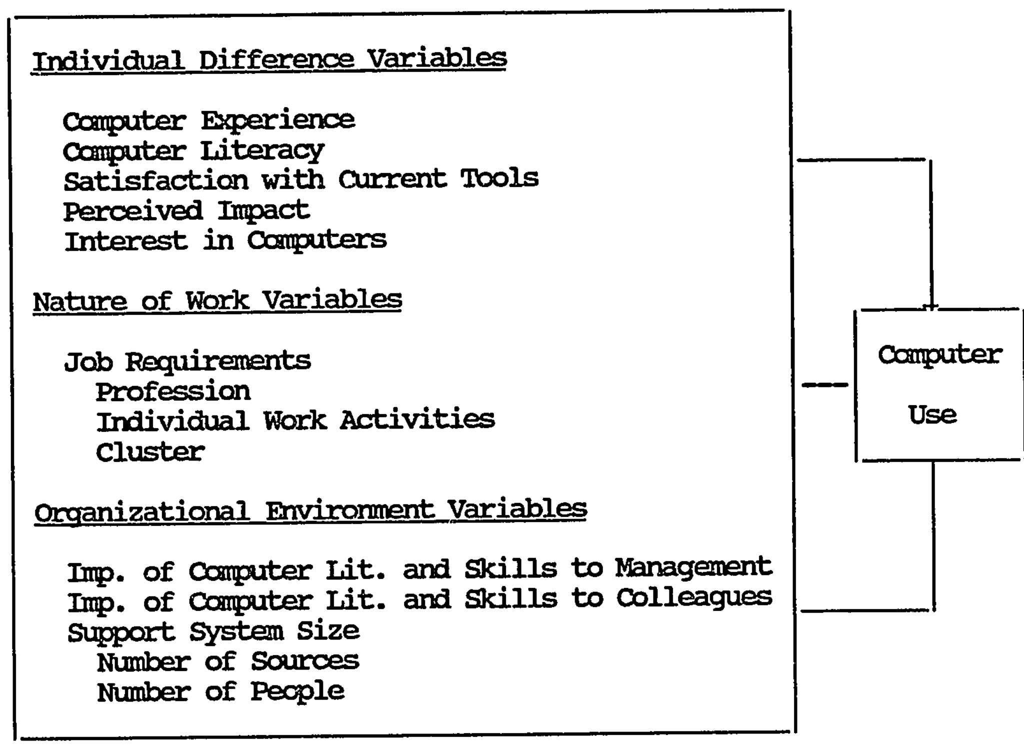
Selection of Model Variables

Following the identification of potential predictors of scientists' computer use, evidence supporting use-variable relationships was examined in order to identify predictors for inclusion in the study model. A wide variety of variables has been suggested, however, little empirical evidence is available to support these computer use-variable relationships. In addition, operational definitions of variables have varied widely. As a result, evidence of all sorts was considered, including empirical, observational, experiential, anecdotal, and opinion data. Technology-specific variables (e.g., ease of use, design features) and organizational variables (e.g., organizational structure, organizational size) were not of interest to the research sponsors and thus were not considered. The relationships suggested by the available evidence are summarized in Figure 1. Variable definitions and a review of the evidence supporting the selection of model variables follows.

A review of the literature revealed only two studies focusing exclusively on scientists' use of computers (Pope, 1984; 1985). As a result, most of the evidence for use-variable relationships comes from work concerned with non-research environments. Although few studies have examined scientists' computer use, a number of investigations have explored computer use in other professions. Most of this research has been concerned with computer use in the "office." The office has usually meant the business office, with little distinction between office computer users (e.g., clerical

Figure 1

Model summarizing expected use-variable relationships



administrative, managerial, professional; e.g., Collopy, 1988; Kublanow, Durand, and Floyd, 1985; Weber, 1988). Few studies have provided adequate information to begin to evaluate the similarities and differences between the scientific and business offices. The limited evidence that does exist, however, provides little support for the generalizability of this research to the scientific office. For example, there appear to be few similarities between the work activities and characteristics of the work environments reported in studies of business offices (e.g., Helander, 1985; Parsons, 1985; Stewart, 1985) and scientific offices (e.g., Harris and Brightman, 1985). These environments differ in levels of work autonomy, work structure, work deadlines, and in their work evaluation methods, as well as in detailed tasks performed. Likewise, studies suggest large differences in computer use. Pope found a command vocabulary (a measure of computer use) of 87 commands among research scientists. In contrast, using the same measure in business offices Collopy (1988) and Kublanow, Durand, and Floyd (1985) found average command vocabularies of 14 and 15 commands respectively. In sum, the applicability of findings in these environments to the scientific workplace must be considered tenuous at best.

Computer experience. Numerous authors have suggested a computer use-computer experience relationship, with more experienced users employing computers more often (e.g., Grantham and Vaske, 1985, reported greater use of a voice-mail system by more experienced users; Miller, 1988, reported more effective personal computer use by more experienced users). Computer experience was included in the study model as a likely predictor of scientists' computer use.

Typically previous studies have operationally defined this variable as days or months of previous computer use. However, it seems likely that most authors suggesting computer experience as a determinant of computer use have intended it to serve as an indirect assessment of a more complex construct involving an ill-defined mix of factors such as computer expertise, knowledge, or skill. In studies of newly introduced technologies or in the evaluation of the design of new technologies, where exposure to the technology of interest is controlled, this operational definition may be an adequate approximation to the construct of interest. However, when the technologies employed have been available for a number of years, the viability of this operationalization appears questionable. For example, in a research organization it seems likely that many scientists will have used computers for several years but still be "inexperienced" computer novices, and many other scientists will be relatively new users but be "experienced" experts.

One alternative to measuring computer experience in this fashion would be to have scientists subjectively rate their own level of experience in relation to their peers. Presumably scientists would interpret experience as something more than "years of computer use" and their ratings would better reflect the intended construct. In this study computer experience was operationalized both as years of use and as self-estimated experience. Self-estimated experience was expected to bear a stronger relationship to computer use than years of use.

Computer literacy. Several studies have either directly or indirectly suggested computer literacy as a variable closely related to computer use (e.g., Konar, Kraut, and Wong, 1986; Mynatt, Smith, Kamouri, and Tykodi, 1986; Pope, 1985; Tornatzky, 1985). Computer literacy was included in the study model as a likely determinant of computer use, with more literate computer users expected to employ computers more often. However, a review of the literature revealed no commonly accepted definition or measurement method for this variable. In fact, while the term is commonly used in the literature, nearly every author appears to have employed a different operational and conceptual definition of the construct. For example, some authors have treated literacy as equivalent to computer experience (e.g., Carpenter, 1986), others have defined literacy as computer command vocabulary (e.g., Pope, 1985), and still others have treated literacy as a multidimensional construct encompassing various aspects of computer knowledge, skill and understanding (e.g., Konar, Kraut, and Wong, 1986; Mynatt, Smith, Kamouri, and Tykodi, 1986).

After reviewing the literature, the most complete consideration and definition of computer literacy was judged to be that found in Konar, Kraut, and Wong (1986); their definition was adopted for this research. These authors defined computer literacy as having three equal components: awareness, skill and knowledge, with each component measured on a continuum (from high to low). Awareness represents an individual's familiarity with the capabilities, advantages, limitations, and impact of computer technology. Skill represents an individual's skill at using computers, both in programming and in using existing software tools. Finally, knowledge represents an individual's level of understanding of computer equipment and how systems function internally.

This definition was thought to be compatible with the work and ideas of a number of other authors working in a variety of somewhat related areas. For example, the awareness component of literacy appears to be similar to what Rockart and Flannery (1983) refer to when they point to the need for user education in the capabilities of software. It is also consistent with Mynatt et al.'s (1985) literacy definition, which includes an understanding of the social and psychological impact of computers. The skill component of literacy is compatible with Pope's (1985) operational definition of literacy as being a user's computer command vocabulary, and with Mynatt et al.'s (1986) definition which includes an ability to control a program and to create a program to achieve desired ends. Finally, Konar, Kraut, and Wong's (1986) knowledge component of literacy would seem to be similar to what Tornatzky (1985) refers to in noting that employees operating advanced technologies should have an understanding of the principles behind their use and the larger systems of which they are a part. In this study literacy was operationalized as the average of participant self-ratings of their awareness, skill, and knowledge as defined by Konar, Kraut, and Wong (1986).

Satisfaction with current tools. Satisfaction with current tools refers to scientists' satisfaction with the hardware and software tools used to accomplish their work. Previous authors have consistently operationally defined this variable as self-reported satisfaction. Nevertheless, findings from studies examining the relationship between use and satisfaction have been mixed (Licata, 1982; Zmud, 1979). Most authors report a weak positive relationship between use and satisfaction (e.g., Licata, 1982); however, others have found no evidence for a use-satisfaction relationship (e.g., Bikson and Gutek, 1983). At least one author has reported a negative relationship between use and satisfaction (Rockart and Flannery, 1983). Satisfaction with current tools was included in the study model as a determinant of computer use, with greater satisfaction expected to correspond to greater use. However, due to previous mixed findings, this relationship was not expected to be as strong as the relationships between computer use and other model variables. Scientists were asked to estimate their satisfaction with their current tools, in a manner similar to previous studies.

Perceived impact. Some authors have informally observed when studying the implementation of advanced technologies, that for computers to be used extensively the user must see a direct opportunity to improve personal productivity (Ehrlich, 1987; Kublanow, Durand, and Floyd, 1985). In contrast, Anderson, Jay, Schweer, and Anderson (1985) found that users' recognition of potential benefits was unrelated to their current use of computers. My experiences in product development activities suggest that the findings of Anderson et. al. (1985) derive from asking the user about the potential impact of computer use, as often occurs in the assessment of new technologies, rather than asking about the current impact of computer tools regularly employed by the user.

The perceived impact of computer use on overall productivity was included in the study model as a likely predictor of computer use. Impact was operationally defined as scientists' ratings of the impact of their computer use on their overall productivity, with higher ratings expected to correspond to greater computer use.

Interest in computers. Pope (1985), through a series of interviews, identified interest in computers as an important determinant of scientists' computer use, with greater interest corresponding to greater use. Only one other study was found which mentioned interest in computers (Konar, Kraut, and Wong, 1986). This variable was included in the study model as a determinant of use, with greater interest expected to correspond to greater use.

The lack of attention paid to interest in computers may be at least in part attributable to its implicit inclusion as a part of a larger "attitude toward computers" variable. A surprisingly large number of studies have investigated "attitude toward computers" (e.g., Anderson, Jay, Schweer, and Anderson, 1985; Grantham and Vaske, 1985; Jackson, Vollmer, and Stuurman, 1985; Licata, 1982; Popovich, Hyde, Zakrajsek, and Blumer, 1987; Singer, Sacks, Lucente, and Chalmers, 1983; Zmud, 1979), with most studies addressing either the effect of attitudes on implementation success or system use. However, a review of these studies provides no further insight into this variable. This variable is measured differently by nearly every author according to whatever unsubstantiated behaviors are thought to reflect a user's "feelings" about computers. In contrast, for this research, interest in computers was operationalized as a scientist's self-rated interest in relation to his or her peers.

Job requirements. Several studies have suggested a job requirements-computer use relationship, although the operational definition of job requirements has varied considerably, and the nature of this variable relationship has not been well defined. This variable was included in the study model as a predictor of computer use.

Scientific job requirements have been defined by several authors in terms of work activities composing the "scientific office" (e.g., Harris and Brightman, 1985; Hirschheim, 1986; Stewart, 1985), however, the focus of these studies has not been on differences in scientists' computer use. Collopy (1988) found that use patterns (i.e., the distribution of use across activities) were related to job requirements (i.e., the nature of work performed: primarily verbal or analytic). The findings of Pope (1985) and Kublanow, Durand and Floyd (1985), compared in Figure 2, likewise suggest a difference in use patterns based on job requirements. In this comparison job requirements is defined in terms of the type of work environment studied (i.e., a research environment versus a business environment). Finally, a use-job requirements relationship is consistent with Weber's (1988) finding that individuals' perceptions of the impact of computer use are correlated with Position Analysis Questionnaire job dimension scores (see McCormick, Jeanneret, & Mecham, 1972, for a review of the Position Analysis Questionnaire).

In the current research the job requirements construct was operationalized in three ways with the collection of two sets of

Figure 2

Computer use patterns for scientists and business office workers

Activity Categories	Percent of computer use time 0 5 10 15 20 25 30 35 40 45
electronic mail/ communications	PPPPPPPPPPPPPPPPP KKKKKKKKKKKKKKKKKKKKKKKKKKKKKK
data analysis & graphics	PPPPPP KKKKKK
document creation, edit, browse	PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP KKKKKKKKKKKKKK
file management	PPPPPPPPPPPP KK

P - percent of users' total computer use time reported by Pope (1985) in a research organization

K - percent of users' total computer use time reported by Kublanow, Durand, and Floyd (1985) in a business office

Note: Both authors recorded computer use with the CMON use monitoring programs used in the current investigation. Where categories differed use was recategorized to permit comparisons.

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data: self-reported profession and work activity analysis data (hours per week spent performing 11 categories of work activities, and the importance of each activity in performing work successfully). From these data the final derived operational definitions of job requirements were (a) profession, (b) individual work activity time and importance measures, and (c) empirically derived clusters of scientists (i.e., individual scientists grouped together through a cluster analysis of work activity data). Profession and cluster membership were expected to be related to computer-use and several individual work activity categories (e.g., the time spent on, and the importance of, data analysis activities). However, no previous research is available to permit a priori hypotheses regarding the nature of these relationships.

Importance of computer literacy and skills to management and Colleagues. A number of characteristics of scientists' work environments no doubt influence their computer use. The relationships between such variables and computer use have been studied most extensively in the context of implementing advanced technologies in manufacturing, and to some extent in the business office (e.g., Bikson, Gutek, and Mankin, 1981; Davis, 1986). While it is difficult to generalize this body of literature to an established or "routinized" research environment, where computers have been a regular part of the work process for more than a decade, it seems likely that the norms and expectations of managers and co-workers will influence ongoing computer use as well as implementation success. To begin to explore these influences scientists were asked to rate the importance placed on computer literacy and skills by their manager and colleagues. It was expected that perceptions of greater importance would correspond to greater computer use.

Support system size. Anyone who has used a computer as part of their work will appreciate the value of an effective computer support system. In most instances the term "computer support system" has been used to refer to the formal resources made available by an organization to its employees. These resources might include support staff, manuals and other training materials or courses, vendors, and in some instances conference disks. However, this definition of support systems fails to take into account the number of informal sources of support available to organization members. Examples of informal computer support sources include work colleagues, other friends and acquaintances, user groups, and journals. Experience suggests that, within a research organization, a scientist develops a network for computer support from among the myriad of formal and informal options available. These support networks are probably similar to scientists' support networks for other types of information (for a review of network characteristics see Allen, 1977; Keller and Holland, 1978; 1979; 1983; and Pelz and Andrews, 1966). If this is true then the exact make-up of individual scientists' computer support networks, the size of networks, and the extent of their use can be expected to vary considerably.

Very few studies directly address aspects of computer support networks. Only Lee (1986) and Conrath, Irving, Thachenkary, Zanetti, Ratz, and Wright (1982) have attempted to assess directly some aspect of individual or organizational computer support systems. Only Lee (1986) provides data on support system use.

Lee's (1986) findings highlight the importance of informal as well as formal sources in individuals' use of support systems. Several authors have addressed issues involving the design of support systems for individual computer products (e.g., Cohill and Williges, 1985; Ross, 1987). However, these studies provide little insight into individual or organizational support systems. The work of Lee and others highlights a tacit assumption of most researchers and computer product manufacturers: that more and better support will lead to greater computer use.

In this study, support system size was expected to be related to computer use, with greater size corresponding to greater use. Computer support system refers to the formal and informal support sources available to scientists. Individual support networks or systems are the subset of sources individual scientists employ. Support network size was operationalized as both the number of categories of sources used (e.g., journals, colleagues, consultants), and the number of people with which a scientist discusses or exchanges computer-related information on a somewhat regular basis. These two measures were similar to those employed by Allen (1977), Keller and Holland (1983), and Pelz and Andrews (1966) in their studies of scientific and administrative information support systems, and Lee's (1986) study of personal computer support system use.

Model Variable Relationships

The fragmented nature of the literature reflects an area of investigation in its infancy, with little consistency in operational definitions of variables or research methods, and little empirical evidence upon which to draw to construct a model of factors determining scientists' computer use. There is a clear need for research aimed at the development of such a model, along with associated conceptual and operational variable definitions and appropriate research methodologies. To address this need, a descriptive model was derived from the literature. The model contains variables considered likely to influence scientists' computer use (i.e., variables for which some evidence exists supporting a variable-computer use relationship). This model is intended to serve as a building block in the development of more complete models detailing the complex network of variables influencing computer use. In order to evaluate this model it was necessary to develop conceptual and operational variable definitions and appropriate research methods. The model evaluation included assessment of: (a) the degree of relationship between computer use and model variables; (b) the extent to which individual scientists' computer use could be predicted from a linear combination of model variables; (c) the degree of inter-relationship among model variables.

In addition to relationships between model variables and use, several variables were expected to be inter-related. However, previous research provides very little evidence upon which to build a priori hypotheses regarding these relationships. At least four such variable relationships have been previously suggested. Specifically, Pope has discussed the likely existence of a computer literacy-interest in computers relationship, and Konar, Kraut, and Wong (1986) have suggested a job requirements-literacy relationship, but these authors did not provide data in support of the suggested relationships. Weber (1988) has provided limited evidence for a job requirements-perceived impact relationship. Finally, Carpenter (1986) has suggested a computer literacy-computer experience relationship (by defining these variables as equivalent). Of these relationships, only Weber (1988) presents data adequate to support an a priori hypothesis (that job-requirements and perceived impact will be related).

Measurement of Computer Use

A major hurdle in the effective study of computer use involves developing acceptable operational definitions of computer use (Trice and Treacy, 1988). For example, use could be measured as time spent actively using a computer, time spent logged onto a computer (i.e., time where the computer is active and the user monitors the system, but does not interact regularly), the variety of uses to which computers are applied, or the amount of computer resources consumed. Nearly all previous studies measuring computer use have operationalized it as self-reported amount or proportion of time spent actively using a computer (e.g., hours per day or per week of use). As a result, a questionnaire measure of hours per week of computer use was developed.

Several authors have called for the development of computer-based measurement tools (e.g., Helander, 1985; Tornatzky, 1985), however, only one such tool was reported in previous studies (CMS monitor or CMON; Collopy, 1988; Kublanow, Durand, and Floyd, 1985; Pope, 1985). CMON provides four alternative measures of computer use. The four measures CMON records are net elapsed time, net active time, command vocabulary, and number of interactions. Net elapsed and net active time are alternative techniques for estimating the amount of time spent using a computer. These measures are intended to be equivalent to questionnaire-based measures of time spent using a computer and have been the primary measures of interest in previous studies. Number of interactions and command vocabulary represent counts of the number and variety of commands issued respectively. "Issuing commands" refers to the way in which a computer user interacts with computer systems that run the VM operating system, the primary system used at the sites studied with CMON. These measures of use reflect the intensity and breadth of a user's computer use.

Rarely has evidence been presented in support of the reliability or validity of questionnaire-based measures of time spent using a computer, and no evidence for the reliability or validity of CMON measures is available. A final study objective was to assess and compare the reliability and validity of a questionnaire-based measure and CMON measures of computer use. CMON measures were expected to be superior to the questionnaire-based measures, due to the ability of CMON to record user data without the subjectivity inherent in questionnaire measures.

Study Objectives and Hypotheses

Objective one. To evaluate the relationships between model variables and scientists' computer use.

Hypotheses. All model variables were expected to be significantly related to scientists' computer use, with greater use corresponding to greater computer experience, computer literacy, satisfaction with current tools, perceived impact, interest in computers, importance of computer literacy and skills to management, importance of computer literacy and skills to colleagues, and support system size.

Objective Two. To assess inter-relationships between model variables.

Hypotheses. Job requirements and perceived impact were expected to be significantly related. Other variable relationships were expected to be uncovered, however, available evidence did not support further a priori hypotheses concerning these relationships.

Objective Three. To develop a linear predictive model of scientists' computer use.

Hypotheses. A linear predictive model developed from study variables will account for a significant amount of the variance in scientists' computer use.

Objective Four. To develop reliable and valid measures of study variables, and to compare and contrast questionnaire measures of computer use with computer-based measures of use.

Hypotheses. Acceptable measures of study variables will be derived. Self-estimated computer experience will prove to be a better measure of computer experience than will years of use. Computer-based measures of computer use will prove to be better measures than a questionnaire-based measure of computer use.

METHOD

Research Site

This research was conducted at the IBM T. J. Watson Research Center (here after referred to as Watson). Watson is the largest of four IBM research sites and is located in Yorktown Heights, New York. The primary mission at Watson is the conduct of basic research in a wide variety of scientific areas and disciplines. There are five research departments at Watson: (1) Physical Sciences, (2) Logic, Memory and Packaging, (3) Mathematics, (4) Computer Science, and (5) Input-Output Technology. The staffs of these departments are divided approximately equally between research scientists (RSMs) and technicians. Technicians, who were not included in this study, include most organizational support staff (e.g., research assistants and secretaries). Participants for this research were drawn from the RSMs of the first three departments. Computer Science was excluded for several reasons, but most importantly because their work is not science in the traditional sense. Rather it involves what might best be termed creative engineering and programming. Input-Output Technology, the smallest department at Watson, was excluded in part because they are geographically separate from the units included in the study and may be subject to different environmental influences. This research was sponsored by the Computing Systems department, a support (i.e., non-research) department responsible for providing scientists with computer resources and support.

Participant Sampling Strategy

Participant recruitment proceeded in the following manner. First, the research team (the research sponsors and I) met individually with each department's senior managers, both to ensure their cooperation and to obtain lists of department RSMs. All senior managers agreed to allow their RSMs to take part on a volunteer basis. One hundred twenty-five scientists were selected randomly from a population of 422 RSMs. Lists of scientists were provided by their senior managers. I approached scientists individually to solicit their participation. Participation was voluntary and could be discontinued at any time. Eighty percent of those approached agreed to participate (n = 104; see Table 2), 12 percent declined, and eight percent agreed to participate on an "if needed" basis. That is, they preferred not to take part or had a schedule conflict, but they consented to participate if needed (they were excluded from the study). Reasons for declining to participate were recorded, and nearly all involved the time the study would require or schedule conflicts. Each scientist who agreed to participate signed up to attend one of several data collection meetings.

The mean age of scientists in the study was 40. Ages ranged from 27 to 64, with scientists fairly evenly distributed across this range. The average scientist had spent 10.5 years working for IBM, and 10 years working for the IBM research division. One hundred participants held Ph.D.s, three held Masters degrees, and one held a Bachelors degree. Self-reported professions are listed in Table 3.

Table 2

Participant population and numbers of scientists participating in the study questionnaire and computer-based measurement

Department	Population	Sample Questionnaire	Sample CMON
Mathematics	78	18	10
Logic, Memory and Packaging	237	59	52
Physical Sciences	107	27	19
Total	422	104	81

Table 3

Participant self-reported professions

Number of Participants	Discipline
8	Computer Science
34	Physics
8	Mathematics
5	Engineering
15	Materials Science
11	Chemistry
1	Physics/Chemistry
13	Electrical Engineering
2	Physics/Electrical Engineering
2	Physics/Engineering
1	Silicon Technology
1	Astrophysics
2	Linguistics

Procedure

There were two components of data collection: CMON recording of participant computer use, and a questionnaire to measure all model variables and computer use. During initial recruitment participants signed up to attend one of several scheduled 75 minute data collection meetings. The number of participants per meeting ranged from three to seven, with an average of approximately five scientists per meeting. Approximately three meetings per week were held over seven weeks until all questionnaire data were collected. Meetings were held in various conference rooms at Watson over a variety of times of day and days of the week to accommodate scientists' schedules.

Data collection meetings began with a brief overview of the study. This discussion reviewed the purpose and requirements of the study, which had been previously discussed during recruitment. The next step in the meetings involved completion of the questionnaire. Scientists were encouraged to take their time to consider carefully their responses. I remained in the room to answer any questions. Administration of the questionnaire required approximately 40 minutes.

Within a month following participation in a data collection meeting I met individually with the participants to install the CMON data collection program. All 104 participants completed the questionnaire portion of this study, 81 also completed the CMON data collection (see Table 2). Most of those who did not complete the computer-based data collection were unable to do so either due to technical problems with the program, long periods of time away from the Watson research center, or an unwillingness to commit the time necessary to provide CMON feedback. No significant differences were found in characteristics of those who did and did not provide CMON data.

Data Collection Instruments

To develop the tools for exploring scientists' use of computers, use was classified into three general categories: (a) mainframe use, (b) PC/Workstation use, and (c) use of computerized laboratory equipment. Mainframe use refers to the use of large multi-user "mainframe" computer systems. These systems are typically located in centralized areas, are maintained by computer support staff, and are usually accessed via a terminal from one's office or home. At Watson these systems run the VM and MVS operating systems. Mainframe systems typically have considerably more processing power and storage capacity than do PC/Workstations. A PC/Workstation typically resides in the scientist's office or lab and is intended for his or her exclusive use. PC/Workstations typically run a version of one of the following operating systems: MS-DOS, OS2, or UNIX. In addition to serving as a computer for accomplishing work, PC/Workstations can act as terminals to mainframe computers. In this study any use of a PC/Workstation as a terminal was treated as mainframe use. Finally, many scientists today use laboratory equipment that includes some form of computer-processing capability. The use of such equipment was not examined in this study.

The use of mainframe computers via the VM or MVS operating systems and the use of PC/Workstations was examined in section C of the questionnaire (Appendix A). In addition, VM-based mainframe use was explored via CMON, which permitted the unobtrusive recording and measuring of aspects of scientists' computer use.

Computer Use Monitoring Programs

A set of usage monitoring programs (CMS Monitor: CMON) were used to record and measure aspects of participants' mainframe computer activity on the VM operating system. These were enhanced versions of the CMON programs used by Pope (1985), Collopy (1988), and Kublanow, Durand, and Floyd (1985). To understand the data collected with CMON it is necessary to understand how a computer user interacts with a mainframe computer that runs the VM operating system. VM operates in half-duplex mode. A result of operating in half-duplex mode is that the computer only responds (i.e., processes information) when the ENTER key is pressed (or other keys set to act as enter keys, such as personal function keys). When the ENTER key is pressed key words (commands) located in a specific entry area on the computer screen are processed. For example, if a user wanted to write a report he or she might type the following command in the specified entry area and press the ENTER key:

XEDIT REPORT ONE

In this example XEDIT is the command issued; it will cause the file REPORT ONE to be opened for editing by the user. The XEDIT command would now be considered active until the file REPORT ONE is closed and exited. After opening the file the user would type in the file contents. However, these entries would not be processed by the mainframe system until a command is issued, such as a command instructing the computer to enter and save this new information. Thus after typing in the file contents the user might issue a SAVE command (type SAVE and press ENTER). When finished the user closes and exits the file, as mentioned above.

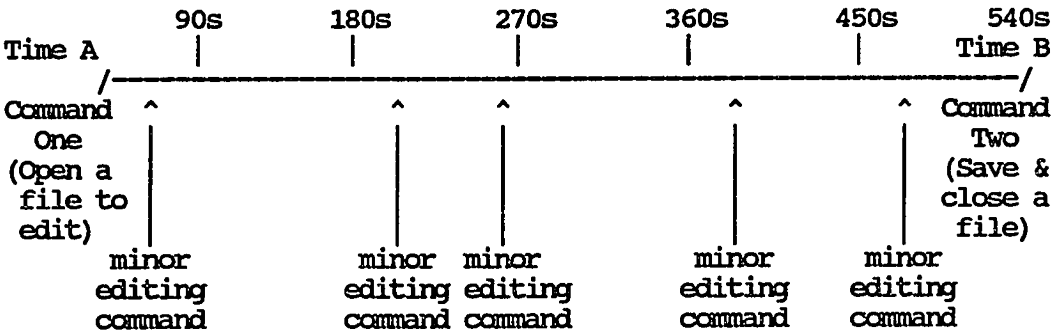
In contrast, most PC/Workstations operate in full-duplex mode. In this mode the computer responds to every key press. Thus if the user were creating and editing REPORT ONE on a PC/Workstation, rather than on a mainframe, the PC/Workstation would respond to (i.e., process) each keystroke. Thus each keystroke would be entered into the computer immediately, eliminating the need for issuing a SAVE command.

For this study CMON was programmed to operate as follows. For each scientist it recorded every VM command issued during 12 randomly selected work days over a period of approximately two months. For each recorded command the following data were collected: net elapsed time and net active time. Net elapsed time is the time elapsed between a command being issued and the completion of the processing of that command. To obtain the net active time for a command net elapsed time is divided into 90 second periods, and those periods during which "activity" takes place (i.e., nested commands are issued) are summed. Figure 3 illustrates these measurements.

Four alternative operationalizations of the computer use construct are derived from data collected with CMON. These

Figure 3

Illustrations of the recording of net active and net elapsed CMON measures



Measure Definitions
Net elapsed time = 540 seconds
Net active time = 360 seconds (1st, 3rd,5th, and 6th 90s periods)

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measures were net elapsed hours per week, net active hours per week, command vocabulary, and interactions per week. Net elapsed and net active time are alternative measures of time spent using a computer. These measures are intended to be equivalent to traditional questionnaire-based measures of time spent using a computer. Nearly all previous studies that have reported use-time, with questionnaires or with CMON, have done so in units of hours per day or per week. To be consistent with previous research net elapsed time and net active time were also calculated as hours per week. This was achieved by summing the net elapsed times or net active times for all recorded commands, dividing the sum by 12 (the number of recorded days), and then multiplying by five. Command vocabulary, as the name implies, represents a count of the number of unique commands recorded for a scientist. Interactions per week represents a scientist's average number of commands issued per week. These measures are consistent with those derived from CMON data by Collopy (1988), Kublanow, Durand, and Floyd (1985), and Pope (1985). These measures reflect the intensity and variety or breadth of a scientist's computer use.

Data were collected in a fashion transparent to participants. For each participant, collection with CMON involved three steps. First, I met with the participant to set up the CMON program to operate on the individual's userid. This involved entering two commands into the participant's profile (a set of commands automatically executed when one logs onto the VM system), and at times making other profile adjustments to ensure CMON operated correctly. It was also necessary to make several entries into a special CMON userid that was used to collect and store participants' data files. Once set up, the operation of CMON was reviewed.

The second step of CMON data collection involved building and adjusting a "filter file" for each participant. This file contained a list of commands that had to be deleted from a participant's recorded commands. There were two sorts of commands that had to be filtered from participant records: system commands and minor editing commands. The nature of VM is such that commands issued by a user often cause additional system commands to be issued. These commands are not directly issued by a user and would not be recognized when feedback was requested, but they are recorded by CMON. It is not possible in advance to know the unique command vocabulary of individual scientists, and CMON cannot be designed to ignore system-issued commands without first knowing a scientist's command vocabulary. Thus several days of recording were necessary during which I typically met with each participant several times to review the recorded files and identify commands that should be filtered out.

In addition, when a user issues a command to invoke a particular software tool or software package such as an editor he or she will issue numerous commands while using that tool. For example, an individual might move a cursor up and down, cut and paste text, or move blocks of text. Minor editing commands such as these are not the concern of this research and were likewise identified and filtered out. The final step in collecting an individual's CMON data involved actual data recording and feedback. I met regularly with each individual to review his or her files (i.e., after every two to four days of data collection depending on the complexity of individual files) to ensure accuracy of filtering.

CMON Data Reliability and Validity

There were two potential threats to the reliability of CMON-based measures. First, various problems with the VM computer systems could cause portions of CMON data to be lost. To avoid this problem I met periodically with each participant to review recorded data and ensure its integrity. Over the course of the investigation two files were judged to be incomplete; they were discarded and new files were recorded. The second threat to reliability involved the filtering of participant records to remove system-issued commands and minor editing commands, and their associated measures. Accuracy in filtering was controlled through the use of filter files, as previously described, and by reviewing all recorded files during periodic meetings with participants. In these meetings, when a command was identified by the participant as appropriate for filtering (missed by the filter file), it was manually removed from the data file.

Previous studies employing CMON have not provided evidence for the validity of its measures, implicitly relying on the high face validity associated with measures recorded by a computer system. In addition to this face validity, in this study types of data were collected to assess the validity of CMON measures. While none of these lines of evidence independently provides strong evidence of measure validity, taken together they provide a basis upon which to judge the resulting measures.

First, the content validity of CMON measures was assessed by evaluating the degree to which the measures derived are representative of overall computer use. Next, the construct validity of the four CMON measures was assessed in three ways: (a) by comparing CMON data in the current study to CMON data in other studies; (b) by comparing the results of the questionnaire measure of use to the CMON measures of use; and (c) by examining expected model-computer use relationships.

The representativeness of CMON measures was explored in two ways. First, the extent of non-VM system use (measured as the number of categories of activities for which scientists reported using a non-VM system as their primary computer system) was examined. The greater the use of non-VM systems (systems not recorded by CMON) the greater the risk that CMON data will not be representative of overall use. Second, correlations between CMON measures and the use of non-VM systems were calculated. A significant negative correlation would suggest that greater use of alternative systems was associated with reduced CMON measures of use. This finding would suggest that some bias may exist in the CMON measure (i.e., the representativeness of the CMON measure may vary with the level of computer use).

As expected, VM-based mainframe systems were scientists' most commonly used computer systems. However, the extent of non-VM systems use was greater than had been previously reported (Pope, 1985). Scientists reported using non-VM system in performing 2.4 of 11 categories of work activities, and a VM-based system for 5.3 of 11 categories of activities. Correlations between CMON measures and the number of categories of activities performed with non-VM systems were calculated. Significant negative correlations were found for net active hours per week ($r = -.26$, $df = 79$) and net elapsed hours per week ($r = -.22$, $df = 79$), but not for interactions per week ($r = .10$, $df = 79$, $p > .05$) or command vocabulary ($r = -.09$, $df = 79$, $p > .05$). These findings provide limited support for the representativeness of interactions per week and command vocabulary measures, and do not support net active or net elapsed hours per week.

CMON measures obtained in previous studies were consistent with (provided support for the validity of) command vocabulary, but not net elapsed or net active hours per week measures. CMON measures were expected to be somewhat lower than those previously reported by Pope (1985) in his study of computer use-intensive scientists, but at least as high has those found by Collopy (1988) and Kublanow, Durand, and Floyd (1985) in their studies of business offices. Scientists' average command vocabulary was consistent with this expectation (i.e., 39 commands compared to 87 for Pope, and 14 and 15 commands respectively for Collopy and Kublanow et. al.). CMON-based hours per week of use measures (i.e., net elapsed and net active hours per week), however, were not consistent with this expectation. Average weekly usage in previous studies ranged from 6.7 to 8.3 hours per week. In the current study scientists' averaged 2.3 hours per week of computer use measured as net elapsed time and .5 hours per week measured as net active time. There are at least three factors that may have resulted in these differences. First, filtering of system issued commands was less comprehensive in previous studies (e.g., individual files were not reviewed with participants, filter files were not individually tailored). Second, use of PC/Workstations was greater than in previous studies. Finally, the accuracy of the cues used to signal the beginning and ending of recording may vary with the "computing environment" (i.e., the common uses for which computers are employed, and the ways in which they are used, by the subject population).

All correlations between study measures of computer use were statistically significantly (see Table 4). The correlations between the questionnaire measure (designed to assess construct validity, see page 42) and all CMON measures were relatively small, providing mixed support for the validity of CMON measures. Correlations between CMON measures showed relatively strong convergence, with the correlations between command vocabulary and the two CMON measures of hours per week of use (i.e., net elapsed hours per week and net active hours per week) being somewhat smaller than the others. Overall, these correlations provide little distinction between CMON measures, but suggest that command vocabulary may be the least similar of the four.

A comparison of the questionnaire-based measure of hours per week of use and the two CMON measures (net active hours per week of use, net elapsed hours per week of use) did not support the validity of the CMON measures. Scientists' average hours per week of use measured with the questionnaire was 19.6 hours. This measure was consistent with my informal observations and interactions with study scientists, in that most scientists appeared to actively use computers many hours per week. However, this finding was dramatically different from mean hours per week of use measured with CMON (i.e., 2.3 hours per week measured as net elapsed time, .5 hours per week measured as net active time).

Correlations between CMON measures and variables hypothesized to be related to use provide relatively strong support for the validity of command vocabulary and interactions per week, but not

Table 4

Correlations between all study measures of computer use

	QU	NA	NE	IW	CV
Questionnaire (QU)	--				
Net active hours per week (NA)	.38	--			
Net elapsed hours per week (NE)	.25	.91	--		
Interactions per week (IW)	.40	.75	.61	--	
Command vocabulary (CV)	.34	.54	.42	.80	--

Note: All correlations statistically significant, df = 79, $p < .05$

for net elapsed or net active measures. Command vocabulary and interactions per week were significantly correlated with five of nine interval scaled measures (see Table 5). Net elapsed and net active hours per week were significantly correlated with none and three of these measures respectively.

Taken together these findings were judged to provide adequate support for the validity of command vocabulary and interactions per week CMON measures, but not for net elapsed or net active measures. As a result, net elapsed and net active hours per week of use were not included in further study analyses.

Study Questionnaire

The study questionnaire (included in Appendix A) was developed to assess model variables and computer use. The process used to

Table 5

Correlations between CMON measures and model variables

CMON Measures	INT	EXP	LIT	IMP	SUPN	SUP5	SAT	IMPC	IMPM
Net Elapsed H/W	-.02	.16	.09	.20	.12	.23	.11	.12	.06
Net Active H/W	.17	.28*	.19	.24*	.19	.24*	.03	.21	.16
Command Vocab.	.41*	.47*	.41*	.20	.41*	.24*	.01	.21	.20
Interactions/W	.26*	.35*	.25*	.19	.25*	.23*	.08	.17	.07

df = 79, * p. < .05

Variable key:
Net Elapsed H/W = Net elapsed hours per week
Net Active H/W = Net active hours per week
Command Vocab. = Command vocabulary
Interactions/W = Interactions per week
INT = Interest in computers
EXP = Computer experience
LIT = Computer literacy
IMP = Impact of computers
SUPN = Support system use - number of sources
SUP5 = Support system use - Network size
SAT = Satisfaction with current tools
IMPC = Importance of computer literacy and skills to colleagues
IMPM = Importance of computer literacy and skills to management

develop reliable and content valid questions is described below. Questions were designed to require responses using five point rating scales in a fashion similar to that used in personnel department questionnaires with which scientists were familiar (i.e., with 5 being the low or poor end of the scale and 1 being the good or high end). The direction of the scales was reversed for study analyses (e.g., 5 to 1, 4 to 2) to aid interpretation. Other questions solicited one or two word written responses or time estimates. The development of the questionnaire proceeded in the following manner. For all variables a review of the literature was conducted to identify appropriate measures. No commonly accepted variable measures or definitions were found. Thus it was necessary to develop appropriate measures for the variables studied. Once initial measures were developed, they were iteratively reviewed and rewritten by the research team (the research sponsors, members of the experimenter's department, and the research director, and I) until judged to be satisfactory (i.e., all feedback from research team members was incorporated to their satisfaction). This process included a trial data collection session using my work group. This group included both traditional scientists and computer scientists.

The questionnaire was administered twice to members of the Computer Science department to assess test-retest reliabilities. Twenty-four people completed the first administration; twenty-one completed the second. The time between administrations ranged from two to four weeks, with an average of approximately three weeks. Pearson product moment correlation coefficients were calculated for each scale, a total of 33 correlations in all (all degrees of freedom = 19). The variables, their measurement scales, and test-retest reliabilities are described below.

Job requirements. Two types of job requirements measures were collected. First, scientists were asked to indicate their profession (see Appendix A, section A: Demographics, question five). Reported professions are listed in Table 3 (only professions with at least five members were included in study analyses). Next, in the questionnaire section titled "B: Job Activities" scientists were asked to indicate how many hours per week, on average, they spent in the past year performing each of 11 activities, and the relative importance of each activity in performing their work successfully. This approach to studying scientists' jobs was designed to share and combine a number of features and advantages of several work analysis methods, especially those employed by Bikson and Gutek (1983) and Harris and Brightman (1985). The intention of this analysis was to focus on meaningful units of scientists' work (e.g., generating or collecting data, data analysis or interpretation) that would be easily identifiable, communicable, enduring, and that would allow easy comparison of scientific jobs. In addition, in order to study how computers are applied to scientists' work activities, it was necessary to focus on units of work that would remain part of scientists' jobs with or without the use of computers.

The activity list used in this study was developed in the following manner. First, as an aid in breaking up scientists' work into appropriate units for study, scientific work was conceptualized as typically proceeding through the phases of genesis, conduct and analysis, and communication (Harris and Brightman, 1985). Research genesis involves those activities associated with the inception of a research idea and its development into a research project. Research conduct and analysis involves carrying out research and analyzing and interpreting results. Communication includes activities involved in preparing and presenting or publishing research findings. Next, an initial list of activities was derived from the literature (e.g., Bikson and Gutek, 1983; Harris and Brightman, 1985; Helander, 1985; Parsons, 1985; Weber, 1988), from informal interactions with scientists, and from the expertise of the research team. Activity definitions and examples were developed. This list was then iteratively reviewed, critiqued and revised by the research team. Activity list development also included having members of the my work group and several other scientists generate their own lists, which were then integrated with the existing list. Finally, test-retest reliabilities were calculated for hours per week estimates and importance ratings (see Table 6). For the Administrative, Methods, and Data Analysis work activity categories importance rating reliabilities were noticeably lower than for hours per week estimates, due to greater range restriction in importance ratings (i.e., ratings were relatively uniformly high for Methods and Data Analysis, and low for Administrative activities). The final activity list includes eight "scientific" activities consistent with Harris and Brightmans' research phases, and three non-scientific work activities (see Appendix A, section B: Job Activities, for activity definitions).

Use of non-VM computer systems. To aid in assessing the representativeness of CMON measures (see page 37) a count was taken of the number of activities scientists reported performing with the aid of a PC/Workstation, an MVS-based mainframe system, or another non-VM system (systems not recorded by CMON; viz., non-VM count;

Table 6

Test-retest reliabilities for work activity hour per week estimates and importance ratings

Work Activities	H/W	Imp.
Administrative: business activities or work management	.91	.66
Review: previous research	.66	.68
Ideas: develop, propose or sell your research ideas	.79	.78
Methods: develop methods, including tools, procedures	.92	.67
Theoretical/analytical work	.86	.82
Generate or collect data	.64	.82
Data analysis or interp. (including visualization)	.87	.66
Communicate your research, including papers, reports	.71	.72
Supervisory activities	.81	.83
Help: obtaining or providing information or assistance	.73	.72
Professional: educational activities, societies, etc.	.85	.77

see Appendix A, section C: Systems, question two). The test-retest reliability for this measure was r = .74.

Computer experience. Two measures were developed to assess computer experience. These were: (a) participants' self-judgments of their overall level of experience in relation to their peers, and (b) years of computer use (Appendix A, section D: Computing Experience, questions one and two). Test-retest reliabilities for the two measures were approximately equal (self estimated experience, r = .80, years of use, r = .81). The correlation between these measures was r = .31.

One study hypothesis was that self-estimated experience would provide a better measure of the computer experience construct than the more common "years of use" measure. The relatively low correlation between these measures suggests that they do not precisely measure the same construct. To further evaluate the validity of these measures, relationships between computer experience and other model variables were examined (see Table 7). While no formal a priori hypotheses were proposed concerning relationships between computer experience and other model variables, it is likely that the superior experience measure would bear more and stronger relationships to study variables.

Self-estimated computer experience was significantly correlated with nine of ten variable measures. In contrast, only two of ten correlations with years of use were statistically significant. One-way analysis of variance was used to examine the relationships between job requirements (profession) and experience. As expected, group differences were significant for self-estimated experience (see Table 8), but not for years of use (see Table 9). These ANOVA results demonstrate that self-estimated experience was significantly related to job requirements, while years of use was not.

Overall, computer use and nearly all model variables were found to be significantly related to self-estimated experience. In contrast, most of the relationships between these variables and years of computer use were not statistically significant. As a result, self-estimated experience was judged to be a better measure of computer experience and was used in later analyses.

Computer literacy. A three part measure of computer literacy (see Appendix A, section D: Computer Experience, questions four,

Table 7

Correlations between computer experience and model variables

Variables	Measures of Computer Experience	
	Years of Use	Self-Est. Experience
Computer use		
Hours/week of use	.15	.58*
Command vocabulary	.08	.47*
Interactions per week	.02	.35*
Support system size		
Number of sources	.07	.49*
Network size	.13	.45*
Imp. of computers to colleagues	.11	.26*
Imp. of computers to management	.22*	.47*
Computer literacy	.23*	.78*
Interest in computers	.18	.73*
Satisfaction with current tools	.07	-.17

* $p < .05$

df = 102 for non-CMON measure correlations
df = 79 for other correlations

Table 8

Results of ANOVA with Profession as the independent variable and self-estimated computer experience as the dependent variable

Source	DF	Sum of Squares	F-Value
Model	6	21.17	4.15 *
Error	87	73.94	
Total	93	95.11	

* $p < .05$

Table 9

Results of ANOVA with profession as the independent variable and years of use as the dependent variable

Source	DF	Sum of Squares	F-Value
Model	6	510.68	1.89 n.s.
Error	87	3920.47	
Total	93	4431.15	

five and six) was developed based on the three part definition of literacy proposed by Konar, Kraut, and Wong (1986). These authors defined computer literacy as having three components: awareness, skill, and knowledge with each component measured on a continuum (from high to low). Awareness represents an individual's familiarity with the capabilities, advantages, limitations, and impact of computer technology. The second component represents an individual's skill at using a computer. Knowledge represents the individual's level of understanding of the equipment and how systems function internally. These authors' definitions of the three literacy components were adapted to create three literacy self-estimate questions. These measures were averaged to obtain a single literacy scale. The test-retest reliability for this scale was $r = .93$. The lower bound for the internal reliability of this composite scale, measured as coefficient alpha, was .86.

Hours per week of use. Scientists were asked to estimate the average number of hours per week they spend actively using a computer (see Appendix A, section D: Computer Experience, question three). The test-retest reliability for this question was $r = .68$.

Satisfaction with current tools. Scientists were asked to indicate their overall satisfaction with their current set of computer hardware and software for accomplishing their work (see Appendix A, section E: Current Status, question one). The test-retest reliability for this question was $r = .71$.

Interest in computers. Participants rated their level of interest in computers compared to other scientists at Watson (see

Appendix A, section F: Computing Environment, question one). The test-retest reliability for this question was r = .93.

Importance of computer skills to colleagues. In order to assess the likely influence of co-workers and colleagues on scientists' computer use, participants rated the importance their colleagues place on computer skills (see Appendix A, section F: Computing Environment, question two). The test-retest reliability for this question was r = .77.

Importance of computer skills to management. To assess the influence of management on scientists' computer use participants rated the importance of computer literacy and skills to their management (see Appendix A, section F: Computing Environment, question three). The test-retest reliability for this question was r = .51. An examination of question responses revealed that this low correlation was largely due to limited variability in participant responses (i.e., 11 participants provided the same response on both administrations, four decreased by one on the second administration, and five increased by one). In addition, responses were consistent with expectations. That is, everyone reported computer skills to be important to their management on both administrations (i.e., nearly all ratings were one and two). A measure of exact agreement (coefficient Kappa) was calculated, with Kappa = .67. The question was retained in the questionnaire.

Support system size. Two measures of the size of scientists' computer support systems were developed. The first was a count of the number of categories of sources scientists reported using at least three or four times a year. (viz., number of sources; see Appendix A, section G: Support System, question three). The second measure asked scientists to indicate the number of people with which they discuss or exchange computer-related information on a somewhat regular basis (viz., support network size; see Appendix A, section G: Support System, question five). The test-retest reliabilities for these questions were r = .78 and r = .96 respectively. The correlation between these measures was r = .38. The internal reliability (coefficient alpha) for number of sources was .70.

A principal components analysis was performed on the two measures of computer support system size (i.e., number of sources used, number of people consulted). A single component was obtained with an eigenvalue of 1.38 (see Table 10). As a result, the two support measures were converted to z-scores, and averaged to obtain a single measure of support system size which was used in all further analyses. The internal reliability (coefficient alpha) for this measure was .69.

Impact of computers. Scientists were asked to rate the overall effect of their computer use on their productivity and on their work (see Appendix A, section H: Impact of Computing, question one). The test-retest reliability for overall productivity was r = .90.

Variables Derived from Questionnaire and CMON Measures

In the development of acceptable study measures three variables involving several measures required further analyses. Multiple computer use measures were found to be reliable and valid and were significantly inter-correlated, thus factor analyses were performed

Table 10

Results of principal components analysis using support system measures

Support measures	Factor loadings	Communalities
Number of sources	.83	.69
Support network size	.83	.69
Eigen value		1.38

to determine whether these measures represented single or multiple factors. Likewise, three individual difference variables -- computer literacy, computer experience, and interest in computers -- were highly correlated; a factor analysis was performed to determine whether they represented a single factor. Finally, a cluster analysis was performed on work activity data to determine whether scientists could be grouped into a limited set of unique clusters, as an additional operationalization of the job requirements variable.

Measures of computer use. A principal components analysis was performed with the two CMON-based measures of computer use and the questionnaire measure. A single component "computer use" solution was extracted with an eigenvalue of 2.06 (see Table 11). These three measures were converted to z-scores and then averaged to

Table 11

Results of principle component analysis using measures of computer use

Computer use measure	Factor loadings	Communalities
Hours per week of use	.64	.41
Command vocabulary	.90	.81
Interactions per week	.92	.84
Eigenvalue		2.06

obtain a composite measure of computer use employed in all further analyses. The internal reliability (coefficient alpha) for this measure was .73.

Capability with computers. Three individual difference variables (computer literacy, computer experience, and interest in computers) were very highly inter-correlated (see Table 12). As a result, a principal components analysis was performed and a single individual difference "capability with computers" component was identified with an eigenvalue of 2.52 (see Table 13). These three measures were converted to z-scores and averaged to obtain a composite measure interpreted as an individual's capability with computers. This composite measure replaced computer literacy, computer experience, and interest in computers in all later study analyses. The internal reliability for the new composite measure (coefficient alpha) was .90.

Table 12

Correlations between computer literacy, computer experience, and interest in computers

Variables	Comp. Literacy	Comp. Experience	Int. Computers
Computer Literacy	---		
Computer Experience	.78*	---	
Int. in Computers	.77*	.73*	---

df = 102, * $p < .05$

Table 13

Results of principle component analysis using computer experience, computer literacy and interest in computers

Model variables	Factor loadings	Communalities
Interest in computers	.91	.82
Computer experience	.93	.83
Computer literacy	.91	.86
Eigen value		2.52

<u>Measures of job requirements</u>. As part of the operationalization of the job requirements variable, the FASTCLUS cluster analysis procedure (SAS Institute, Inc., 1985) was employed to determine whether scientists could be meaningfully divided into distinct groups based on their hours per week estimates and importance ratings for the 11 work activity categories. All variables were converted to z-scores for this analysis. Since clustering methods do not result in an optimum clustering solution separate cluster analyses were performed for solutions containing from two to 15 clusters. A logical analysis of these solutions was then performed.

Criteria for choosing between cluster solutions included maximizing the distance between cluster centroids and minimizing the distance between the furthest member of a cluster and its centroid. In addition, as a practical matter, solutions that resulted in one or two clusters containing a lot or very few scientists were less desirable than solutions in which participants were more evenly distributed across clusters. Likewise, a good cluster solution was expected to result in statistically significant and easily interpretable differences between clusters on clustering variables. Finally, the resulting groups were expected to differ significantly in their computer use.

A cluster solution containing three clusters was found to meet all of the above criteria. The groups were found to differ significantly on nearly all clustering variables (see Table 14), and in computer use. Differences between groups on a few key variables

Table 14

Mean hours per week estimates and importance ratings for groups of scientists identified through cluster analysis

Work Activities	Hours/Week				Importance			
	1*	2**	3***		1*	2**	3***	
Administrative	2.1	4.1	3.6	*a	1.4	2.1	1.7	*a
Reviewing Research	2.5	3.1	2.4		2.5	2.5	2.4	
Idea Development	4.1	5.0	1.9	*b	3.2	3.3	2.1	*b
Methods	8.4	3.8	16.6	*c	3.4	2.5	3.7	*f
Theoretical/Analytical	1.4	4.4	5.1	*d	1.1	2.8	3.0	*d
Generating Data	11.2	5.1	4.6	*d	3.7	3.0	2.8	*d
Data Analysis	7.0	5.7	4.3	*e	3.7	3.2	2.9	*e
Communicating Research	4.8	7.7	4.5	*f	3.0	3.6	3.4	*f
Supervisory	.7	3.2	1.1	*f	0.7	1.7	1.0	*f
Obtaining/Providing Help	2.0	2.3	1.8		1.6	2.1	1.9	
Professional	.9	2.7	2.3	*d	1.5	2.6	2.4	*d

* $p < .05$

* Experimentalists
** Communicators
*** Methodologists

Results of a Newman-Keuls post hoc test indicated that:

a - group 2 differed from group 1
b - group 3 differed from groups 1 and 2
c - all groups are different
d - group 1 differs from groups 2 and 3
e - group 1 differs from group 3
f - group 2 differs from groups 1 and 3

suggest that cluster membership was largely determined by the general scientific research cycle, as described by Harris and Brightman (1985). Specifically, one group was found to spend significantly more time generating and analyzing data and rated these activities as more important than the other two groups. This group also fell distinctly between the others in time spent preparing to run experiments (viz., the methods category). These findings suggest a group of scientists in the conduct phase of their research cycle involving necessary experimental set up work, running experiments, and analyzing data. This group was labelled the "experimentalists." A second group was found to spend significantly more time and rate as more important communicating their research, professional activities, and developing research ideas. These findings suggest a predominance of work involving the communications and research genesis phases (i.e., the beginning and end) of the research cycle. This group was labelled the "communicators." Finally, the remaining group was distinguished by its methodological work (viz., the methods category). This group was composed largely of scientists involved in developing the methodological tools needed to conduct experiments (including programming for simulation-based research). This group was labelled the "methodologists."

Finally, to ensure cluster membership represented an operationalization of job requirements distinct from profession, a Chi-Square test was performed. The resulting Chi-Square value was not statistically significant (Chi-Square = 16.89, df = 12, $p > .05$), supporting the use of both cluster and profession as job requirements measures. Overall, with the identification of clusters, three methods of measuring job requirements were available: time estimates and importance ratings of individual work activities, profession, and cluster membership.

RESULTS

Variable Relationship to Computer Use

The first objective of this research was to determine whether model variables were significantly related to scientists' computer use, as hypothesized. All variables were expected to be related to use, with greater computer experience, computer literacy, interest in computers, satisfaction with current tools, importance of literacy and skills to management, importance of literacy and skills to colleagues, and support system size all corresponding to greater computer use. Likewise, job requirements was expected to be significantly related to computer use, although no hypotheses were formed about the nature of this relationship.

Individual difference variables. With the identification of a capability with computers factor (derived from measures of computer literacy, computer experience, and interest in computers) there were three individual difference variables within the study model: capability with computers, satisfaction with current tools, and perceived impact. Table 15 reveals that, as expected, capability with computers and perceived impact were significantly correlated with computer use, however, satisfaction with current tools was not. The direction of the two significant relationships was consistent with expectations, with greater capability with computers and perceived impact positively covarying with greater computer use.

Table 15

Correlations between model variables and computer use

Variables	CU	SS	CC	SC	PI	IC
Computer Use (CU)	---					
Support System Size (SS)	.39*	---				
Cap. with Computers (CC)	.53*	.62*	---			
Sat. with tools (SC)	.03	.09	-.16	---		
Perceived Impact (PI)	.24*	.36*	.47*	-.03	---	
Imp. to Colleagues (IC)	.19	.17	.39*	.07	.16	---
Imp. to Management (IM)	.28*	.29*	.52*	.01	.22*	.74*

df = 79, * $p < .05$

Nature of work variable. Three alternative operationalizations of the job requirements variable were developed in this investigation: individual work activity time and importance ratings, professions, and cluster groupings. Table 16 contains correlations between computer use and both work activity time estimates and importance ratings. Two of the resulting 22 correlations were statistically significant (viz., hours per week estimates for the methods category, importance ratings for the theoretical/analytical category). The two significant correlations were small and no work activity was significantly correlated with computer use both in terms of time estimates and importance ratings.

Table 16

Correlations between computer use and work activity hours per week estimates and importance ratings

Work Activities	Hours/Week	Importance
Administrative	.05	-.15
Reviewing Research	-.03	.05
Idea Development	-.17	.21
Methods	.30*	-.05
Theoretical/Analytical	.11	-.22*
Generating Research	-.20	-.05
Data Analysis	-.10	-.01
Communicating Research	.06	-.04
Supervisory	-.08	.02
Obtaining/Providing Help	-.16	.07
Professional	-.03	-.15

df = 79, * $p < .05$

As a result, individual work activity measures were not employed in further analyses of computer use-job requirements relationships.

Table 17 summarizes mean differences across professions on computer use and model variables, and Table 18 summarizes mean differences across work activity clusters. These differences were identified by performing two way analyses of variance and Newman-Keuls post hoc tests. An initial two way (Cluster membership X Profession) analysis of variance revealed that computer use differed significantly across both cluster membership and professions (see Table 19), as expected. Also, as expected, there was not a significant interaction between cluster and profession in computer use (there was a significant interaction for both the importance of computer literacy and skills to management and support system size).

Table 17

Mean differences for professions in computer use, capability with computers, satisfaction with current tools, perceived impact, importance of computer skills to management and colleagues, and support system size

Study Variable	Professions 1	2	3	4	5	6	7	
Computer use	-.1	-.0	1.6	.4	-.5	-.5	.0	*a
Cap. with comp.	-1.0	-.0	-.7	-.3	.6	.5	.1	*b
Sat. with tools	3.6	2.4	3.1	3.8	2.9	2.8	3.0	*d
Perceived impact	1.3	1.4	1.3	1.3	1.5	1.2	1.2	
Imp. to mgmt.	2.5	3.4	2.5	3.5	3.9	3.5	3.1	
Imp. to coll.	2.4	3.0	2.5	2.8	3.2	3.1	3.1	
Support size	1.1	-.1	.4	.0	-.4	-.0	.0	*c

Professions:
1 = Computer Science
2 = Physics
3 = Mathematics
4 = Engineering
5 = Materials science
6 = Chemistry
7 = Electrical engineering

* Professions differ significantly, and:

a: Mathematics differs significantly from other professions
b: Computer Science differs significantly from other professions
c: Computer Science differs significantly from Materials Science and Chemistry
d: Physics differs significantly from Computer Science and Engineering

Note: Computer use, capability with computers, and support system size were standardized. All other variables were measured using five point rating scales.

Table 18

Mean differences for scientific clusters in computer use, capability with computers, satisfaction with current tools, importance of computer literacy and skills to management and colleagues, and support system size

Study Variable	Experimentalists	Communicators	Methodologists
		Clusters	
Computer use	-.3	-.0	.6 *a
Cap. with comp.	.4	.1	-.6 *a
Sat. with tools	2.9	2.8	2.9
Perceived impact	1.4	1.3	1.3
Imp. to mgmt.	3.5	3.3	3.0
Imp. to coll.	3.2	2.8	2.8 *
Support size	-.3	-.0	.5 *a

* Clusters differ significantly, and (a) methodologists differ significantly from other clusters

Note: Computer use, capability with computers, and support system size were standardized. All other variables were measured using five point rating scales.

Table 19

Summary of cluster membership-by-profession analyses of variance of model variables and computer use

	F-values			Total df
Measure	Cluster	Profession	Interaction	
Computer use	11.53*	10.45*	.83	72
Capability with computers	10.44*	3.62*	1.29	90
Support System Size	10.63*	2.66*	2.27*	90
Perceived impact	.17	.70	.74	86
Importance to management	1.98	1.01	2.58*	89
Satisfaction with tools	.13	3.46*	.45	89
Importance to colleagues	2.26	2.31*	1.05	87
Degrees of freedom:	2	6	10	

* $p < .05$

Newman-Keuls post hoc tests revealed that the methodologist cluster group used computers significantly more than the experimentalists and communicators, and that compared to other professions computer use was significantly greater among the mathematicians.

Organizational environment variables. Relationships between scientists' computer use and two of three organizational environment variables were consistent with expectations, with support system size and the importance of computer literacy and skill to management being significantly correlated with computer use (greater support system size and importance corresponded to greater use; see Table 15). The importance of computer literacy and skills to colleagues was not significantly correlated with scientists' computer use.

Model Variable Inter-relationships

The second objective of this study was to determine whether model variables were significantly inter-related. The single a priori study hypothesis, that computer experience and job requirements would be related, was supported. Two-way (Cluster membership X Profession) between subjects ANOVAs revealed significant differences in capability with computers across professions and clusters (see Table 19; computer experience was one of three measures composing the capability with computers factor). Newman-Keuls post hoc tests indicated that the mathematics profession had significantly greater capability with computers than other professions, and that the methodologists had greater capability with computers than the experimentalists and communicators (see Tables 17 and 18).

Five additional two-way (Cluster membership X Profession) between subjects ANOVAs were performed to assess the relationships between job requirements and the remaining model variables. Clusters and professions were found to differ significantly in support system size. Newman-Keuls post hoc tests revealed that computer scientists had larger support systems than other professions, and methodologists had larger support systems than other cluster groups (see Tables 17 and 18). Professions did not differ in perceived impact, or importance of computer literacy and skills to management. Professions differed in satisfaction with current tools and importance of computer literacy and skills to colleagues. Newman-Keuls post hoc tests did not reveal any significant mean differences (see Table 17). Clusters differed significantly in importance of computer literacy and skills to management, although Newman-Keuls post hoc tests did not reveal any significant group differences (see Table 18). Clusters did not differ in perceived impact, satisfaction with current tools, or importance of computer literacy and skills to colleagues.

Finally, there were eight significant correlations between model variables (see Table 15 again). Greater support system size corresponded to greater capability with computers, perceived impact, and importance of computer literacy and skills to management. Likewise, greater capability with computers corresponded to greater perceived impact, importance of computer literacy and skills to colleagues, and importance of computer literacy and skills to management. Finally, importance of computer literacy and skills to management corresponded to greater perceived impact and importance of computer literacy and skills to colleagues.

Linear Prediction of Use

The third objective of this research was to assess the extent to which a linear combination of model variables could account for the variance in scientists' computer use. A stepwise regression of computer use on the six variables significantly related to use (i.e., profession, cluster membership, capability with computers, support system size, importance of computer literacy and skills to management and perceived impact) was performed, using the method of backward elimination to determine the order of variable entry (see Table 20). The reduction in variance accounted for by the elimination of model variables was statistically significant at steps four and five in the regression, supporting the inclusion of profession and cluster membership in the final regression equation. Likewise, part and partial correlations were significant for profession and cluster membership (see table 21), but not for the other four variables. As a result, a two variable linear model of profession and cluster membership, accounting for 58 percent of the variance in scientists' computer use, was derived from this regression analysis.

Due to the high correlations among some model variables (e.g., capability with computers and support system size; see Table 15) a hierarchical regression analysis was also performed (see Table

Table 20

Stepwise regression of computer use on profession, cluster membership, capability with computers, support system size, perceived impact, and importance of computer literacy and skills to management using the method of backward elimination

Step	Variable Removed	R^2	R^2_{change}	F-Overall	F_{change}
1	Capability with Computers	.63	.01	8.07 *	.88
2	Perceived Impact	.62	.01	8.74 *	.72
3	Importance to Management	.60	.02	9.90 *	.68
4	Support System Size	.58	.03	10.68 *	4.08 *
5	Cluster Membership	.48	.10	10.98 *	6.85 *

$p < .05$

Table 21

Partial and part correlations of profession, cluster membership, capability with computers, support system size, perceived impact, and importance of computer literacy and skills to management with computer use

Variable	Partial Correlation	Part Correlation	F-Value
Profession	.64	.50	6.43 *
Cluster Membership	.29	.18	2.59 *
Cap. with Computers	.13	.08	.88
Support System Size	.18	.11	1.77
Perceived Impact	.17	.11	1.05
Imp. to Management	.18	.12	.11

* $p < .10$

22). The six variables significantly related to computer use were grouped into three sets for stepwise entry into the regression equation. The three sets of variables were: a) profession and cluster membership, b) capability with computers and support system size, and c) importance of computer literacy and skills to management and perceived impact. Variable sets were derived from a priori variable groupings, variable inter-relationships, and relationships to computer use. The members of the variable set A, profession and cluster membership, were grouped because they are both nature of work variables that were developed as measures of job requirements. In addition, they were grouped because they were both significantly related to the variables in set B, but not to those in set C (see Table 19). The members of variable set C were grouped because they were significantly related to the variables in set B, but not to those in set A, and also because the relationships between these variables and computer use were comparatively weak (see Tables 15 and 19). Finally, support system size and capability with computers were grouped because they were significantly related to all other model variables and computer use (see Tables 15 and 19 again).

The order of variable set entry into the regression equation was based on causal priorities derived logically from the findings of this research. Variable set A was entered in the first step of the hierarchical regression because these variables were thought to be factors necessary to obtain significant levels of computer use (i.e., for the most part there must be a work need to expect

Table 22

Hierarchical regression of computer use on three variable sets: (a) profession and cluster membership, (b) capability with computers and support system size, and (c) perceived impact and importance of computer literacy and skills to management

Step	Set Added	R^2	R^2_{change}	F-Overall	F_{change}
1	Set A: Profession Cluster Membership	.58	.58	10.98 *	10.98 *
2	Set B: Cap. with Computers Support System Size	.62	.04	10.02 *	3.18 *
3	Set C: Perceived Impact Imp. to Management	.64	.02	8.07 *	.58

$p < .10$

significant levels of computer use), regardless of the values of other model variables. By extension, it is likely that these variables directly impact the level of computer use, but are not influenced by use. Variable set B was entered next in the hierarchical regression equation and variable set C was entered last. The order of these entries was largely derived from causal priorities suggested by variable relationships with computer use and variable inter-relationships. The correlations between members of variable set B and computer use were greater than between variable set C and use (see Table 15). The members of variable set B were also signficantly related to all model variables, while the members of variable set C were not signficantly related to the members of variable set A (see Tables 15 and 19). These relationships suggest that the members of variable set B are more directly causally related to computer use than the members of set C.

The entry of variable sets A and B in the regression equation produced statistically significant increments in R^2 (see Table 22). The part and partial correlations for variable set A were statistically significant, however, they were not significant for variable sets B or C (see Table 23). As a result, a two set (four variable) linear model of set A (profession and cluster membership), and set B (capability with computers and support system size), accounting for 62 percent of the variance in scientists' computer use, was derived from this regression analysis. However, the inclusion of set B in the equation must be interpreted with caution, since the partial and part correlations for this set were not statistically significant.

Assessment of Professions

To determine whether professions could be characterized by their work activity data, one-way ANOVAs and Newman-Keuls post hoc tests were performed to compare hours per week and importance ratings across professions. Table 24 indicates that computer scientists spent fewer hours per week performing data analysis activities than physicists and materials scientists, and rated these activities as less important than other professions. They also rated generating data as less important than did study engineers.

Table 23

Partial and part correlations of three variable sets: (a) profession and cluster membership, (b) capability with computers and support system size, and (c) perceived impact and importance of computer literacy and skills to management

Variable Set		Partial Correlation	Part Correlation	F-Value
Set A:	Profession Cluster Membership	.66	.53	5.25 *
Set B:	Cap. with Computers Support System Size	.28	.17	2.28
Set C:	Perceived Impact Imp. to Management	.23	.14	.58

$p < .05$

Table 24

Mean hours per week estimates and importance ratings for professions

Work Activities	Hours/Week							Importance						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Administrative	6	2	3	4	3	4	4	1.7	1.5	1.9	2.7	1.7	2.0	1.8
Review Res.	5	2	3	5	3	3	2	3.0	2.9	2.7	3.0	3.0	3.0	2.9
Idea Development	4	4	2	4	5	4	4	3.0	2.9	2.7	3.0	3.0	3.0	2.9
Methods	9	10	15	6	5	10	7	3.0	3.4	3.3	3.2	2.6	3.5	2.7
Theoretical/Anal	7	4	5	3	2	3	3	3.1	2.4	3.3	2.5	1.9	1.9	2.2
Generating Data	3	8	4	9	9	8	5*	2.0	3.4	3.1	3.7	3.4	3.4	2.7*b
Data Analysis	1	7	4	5	7	5	5*a	1.5	3.5	3.4	3.7	3.6	3.5	2.9*c
Communicate Res	7	6	7	7	6	4	5	3.5	3.5	3.1	3.0	3.6	3.0	3.3
Supervisory	2	2	0	1	1	2	2	1.0	1.0	0.3	1.7	1.2	1.2	1.4
Obtain Help	3	2	1	2	3	2	2	1.5	2.0	2.3	1.7	2.0	1.7	1.6
Professional	4	2	3	1	3	2	1	2.5	2.4	2.3	2.2	1.9	2.2	1.8

$* p < .05$

Newman-Keuls post hoc tests indicated greater means for:
- a - physicists and materials scientists
- b - engineers
- c - all other professions

Professions Key:
1 = Computer science 2 = Physics
3 = Mathematics 4 = engineering
5 = materials science 6 = chemistry
7 = electrical engineering

DISCUSSION

This research was designed to address four objectives. The first was to evaluate the relationships between model variables and scientists' computer use. The second objective was to explore model variable inter-relationships, and the third was to develop a linear predictive model of computer use from variables contained in the study descriptive model. As a prelude to these objectives, a fourth objective involved development of reliable and valid variable measures, including measures of computer use. This chapter first reviews findings regarding the study methodology and then reviews findings pertaining to the first three study objectives.

Methodology Development

Perhaps the most time consuming and difficult portion of this research involved the development and assessment of the methodological components needed to conduct the investigation; a problem no doubt common to many areas of study likewise in their infancy. Little previous research was available with the level of methodological rigor necessary to be useful in identifying and operationalizing computer use or variables that influence use.

To begin to make research progress, the research community must begin to develop some common understanding and definition of relevant variables. One objective of this research was to draw upon both formal and informal sources to identify a limited set of variables likely to be significantly related to scientists' computer use, to operationalize those variables, and to develop evidence for the reliability and validity of the resulting measures. This objective appears to have been largely satisfied. Test-retest reliabilities were found to be acceptable for questionnaire-based measures. Likewise, these measures' validities were judged to be acceptable based on expert evaluation of question content, and for some variables the results of factor analyses as well.

The hypothesis that self-rated computer experience would be a better measure of experience than the more traditional "years of use" measure was confirmed. It appears that participants interpreted "experience" to mean something more than how long computer use has been a part of their jobs. These interpretations were apparently consistent with what most authors have intended when employing this somewhat ill-defined construct.

Both profession and cluster membership, but no individual work activity categories, proved to be useful operationalizations of the job requirements variable. This finding suggests that no one work activity significantly influenced scientists' computer use, but that unique sets of activities reflected in professions and in the identified clusters of scientists (through the cluster analysis on work activity data) did play a significant role in determining use. This finding is somewhat inconsistent with previous literature in that studies of use patterns (i.e., the distribution of use across individual work activities; e.g., Collopy, 1988; Kublanow et al., 1985; Pope, 1985) would appear to suggest individual variable-computer use relationships. However, previous authors have not directly addressed relationships between individual activities and overall computer use, and previous studies have in fact operationalized job requirements in ways relatively consistent with this finding (i.e., as nature of work: verbal or analytic; Collopy, 1988; as category of professional: executive, manager, professional, clerical; Kublanow, Durand and Floyd, 1985; however, these authors were restricted to available measures).

The activity analysis method developed in this study provided reliable and valid data, and had several practical advantages. The categories of activities used were relatively meaningful and enduring activities that could be expected to be part of scientists' jobs with or without computers. They were understandable to participants, permitted relatively easy communication with scientists about their jobs, and permitted data collection within necessary time constraints. They also provided a means of exploring jobs across very different types of scientific work. Thus this analytic method may prove to be a useful means of exploring scientists' jobs in future investigations. However, the findings of this study also suggest a need to explore the possible development of a more direct measure of the scientific research cycle. Cluster membership appeared to be heavily influenced by scientists' research cycles, and a more direct measure might reduce measurement error and greatly expedite the measurement process.

A single capability with computers factor was identified from a factor analysis of scores representing computer experience, computer literacy, and interest in computers. Although this factor was not anticipated, it is not inconsistent with previous literature. Previous definitions of these variables have often overlapped considerably. In fact, some authors have treated literacy and experience as equivalent (e.g., Carpenter, 1986). This finding suggests that many of the individual difference factors discussed in the literature can be reduced to a single measurable complex factor reflecting the capability an individual brings to his or her job to employ a computer to accomplish work. This finding has the potential to significantly facilitate the study of the influence of individual differences on computer use by providing a single, broad and comprehensible, measurable variable to replace the quagmire of variables and measures in the literature (i.e., experience, interest, and literacy, as well as "attitude toward computers"; see Zmud, 1979, for a review of relevant literature).

As with capability with computers, a single computer use construct was identified from questionnaire and on-line measures of use. At the outset of this investigation measures of time spent using a computer and measures of variety or intensity of use (i.e., command vocabulary, interactions per week) were thought to reflect distinctly different conceptualizations of computer use. However, this research suggests that these measures reflect a single computer use construct. This finding suggests that several seemingly different conceptualizations of computer use may simply reflect alternative views of a single robust factor. Additional research is needed to determine whether or not alternative conceptualizations of computer use (i.e., different from time or intensity of use), such as the amount of computer resources consumed, combinations of software tools employed, or "productive use" are unique aspects of use, or if they are simply alternative representations of this construct.

Several previous authors have called for the development of computer-based measures of computer use (e.g., Helander, 1985; Tornatzky, 1985). However, only one such tool was identified in the literature (i.e., CMON; Collopy, 1988; Kublanow, Durand, and Floyd, 1985). This research attempted to evaluate the reliability and validity of measures derived from CMON, and to compare and contrast computer-based and questionnaire measures. The primary CMON measures of interest were the two measures of time spent using a computer, however, evidence failed to support the validity of these measures. In contrast, the available evidence supported command vocabulary and interactions per week as reliable and valid measures of use. It appears that previous interpretations of CMON measures of time spent using a computer were inaccurate. What these measures represent is difficult to determine precisely, but a more accurate interpretation would appear to be something like "hours per week of interactive use," including only use periods where considerable keyboard activity takes place.

That command-based CMON measures proved acceptable (i.e., command vocabulary, interactions per week) and time-based measures did not (i.e., net elapsed hours per week, net active hours per week) was largely the result of the inherent difficulty in unobtrusively recording time spent using a computer with that same computer. For a computer to record use, cues must be provided to the computer that indicate when to begin and end recording. The cues employed by CMON (i.e., the instigation and completion of commands) were insufficient. The unpredictable nature of computer use (i.e., the tendency to use a system for limited periods of time spaced unevenly throughout the day), the growing tendency to remain "logged on" to a computer throughout the work day when not actively using a system, and the tendency for considerable use to involve minimal interaction (i.e., few system cues) all combine to make the identification or development of more effective non-intrusive cues a formidable task for future research.

Overall, contrary to expectations, the evidence and experience of this study strongly support the use of questionnaire-based measures of use over CMON and other computer-based measures. Although both types of tools can provide usable measures, the collection of computer-based data proved to be extremely time and labor intensive, requiring several months and numerous meetings with each study participant. In addition, the continued growth in the use of multiple computer systems is likely to require that any future computer-based tool have the capability of recording use on multiple computer systems (a formidable programming task). Future efforts would probably be better served developing multiple questionnaire-based measures of use, and employing valuable participant and programmer time more efficiently. If computers are to be used to measure use, any measurement program should be PC/Workstation based to provide for capturing every participant keystroke. It will be necessary to develop several versions of the program to operate under multiple operating systems, and will require preliminary developmental studies to ensure the data captured by different program versions are in fact equivalent. Finally, capturing time spent using a computer, including times that are not keystroke intensive, will probably require some form of user-initiated signal to start and end recording sessions.

Evaluation of Model Variables

Identification and operationalization of study variables resulted in eight reliable and valid measures for the assessment of use-variable relationships. There were three individual difference variables (capability with computers, perceived impact, satisfaction with current tools), two measures of a single nature of work variable (job requirements: cluster membership, profession), and three organizational environment variables (importance of computer literacy and skills to colleagues, importance of computer literacy and skills to management, support system size). Six variable measures were significantly related to use.

Individual difference variables. Capability with computers proved to be highly correlated with scientists computer use, with greater use corresponding to greater capability. Computer experience, computer literacy, and interest in computers were all expected to be positively related to scientists' computer use, thus this relationship is consistent with a priori hypotheses. As expected, perceived impact was also significantly correlated with scientists' computer use, with greater impact corresponding to greater use. Participants' ratings were uniformly high, and the relationship between impact and computer use was relatively weak.

Informal interactions with participants suggest that ratings were high because computers provide several very basic capabilities to scientists, regardless of their level of use, that would make their work impossible or impractical otherwise (e.g., control of data collection and complex data analyses). In fact, the results of this study suggest that, contrary to the findings and suggestions of several recent authors (e.g., Bikson, Gutek, and Mankin, 1981; Durand, Bennett, and Betty, 1987; Majchrzak, Collins, and Mandeville, 1986; Stewart, 1985; Wessel, 1988), computers are relatively broad-based productivity enhancement tools for scientists. As a result, future research would be better served by a scale more sensitive to differences in relative impact between scientists, rather than the current scale designed to measure absolute impact.

The hypothesis that users' level of satisfaction with their hardware and software tools for accomplishing their work would be related to their overall computer use was not supported. This finding is consistent with the findings of at least one other study (Bikson and Gutek, 1983), and does not support the conclusions of several previous authors (e.g., Licata, 1982; Zmud, 1979). It appears that use is driven by factors other than satisfaction (e.g., job requirements, capability with computers). However, this should not be interpreted as suggesting that the organizational ramifications of dissatisfaction are not serious. Dissatisfaction may adversely impact organizations in numerous ways, such as by reducing organizational commitment and job satisfaction, or by affecting the types of problems scientists choose to study.

Nature of work variables. Overall, both operationalizations of job requirements were significantly related to scientists' computer use. As hypothesized, distinct clusters of scientists were identified from work activity data and these clusters differed significantly in computer use. Specifically, the methodologists used computers considerably more than the experimentalists and communicators. Likewise, scientists grouped by self-reported profession differed significantly in their use, with mathematicians using computers more than their colleagues.

Contrary to expectations, profession proved to be unrelated to cluster membership, with professions relatively evenly distributed across clusters. In addition, both variables contributed significantly and uniquely to the linear model of use. These variables were initially viewed as alternative measures of a single job requirements variable. However, study findings indicate that these measures differ conceptually and should be treated as separate nature of work variables. Conceptually, each identified cluster of scientists reflects the time and importance of unique sets of activities, determined to a large extent by their point in the general scientific research cycle (see Harris and Brightman, 1985, for a more detailed discussion of the scientific research cycle). The defining characteristics of scientific professions studied were not similar to those of the cluster groupings, and were not as clearly established. In this study only computer scientists were distinguishable based on time spent on, or importance of, categories of work activities. Computer scientists spent fewer hours per week at data analysis activities and rated them as less important than several other professions. This finding was relatively consistent with other differences found among professions. Computer scientists were also found to have significantly larger support networks and greater capability with computers than other professions, and had the second highest mean computer use score. Additional work is needed to clarify the factors that distinguish the other scientific professions studied, and the relationship of these distinctions to computer use.

Organizational environment variables. The hypothesized positive relationship between computer use and the importance of computer literacy and skills to management was supported, while the expected relationship between use and the importance of computer literacy and skills to colleagues was not. These variables were originally drawn from studies of the implementation of advanced technologies (e.g., Bikson, Gutek, and Mankin, 1981; Davis, 1986), and these findings indicate that perceptions of management attitudes continue to influence use following successful implementation (i.e., after computers have become a routine part of the work environment). However, they suggest that the perception of colleagues attitudes may not continue to influence use. This finding highlights the need for research on the transition from technology implementation toroutine use, including the description and explanation of shifts in the variables that influence use.

The hypothesis that support system size would be significantly related to scientists' computer use was confirmed, with greater size corresponding to greater use. This finding is consistent with the explicit study assumption that scientists' computer support networks would have many of the characteristics of the scientific information support networks described by Allen (1977), Keller and Holland (1978; 1979), Lee (1986), and Pelz and Andrews (1966) in that the adoption of these authors' measures provided data consistent with expectations. The study of computer support networks and what constitutes effective support remains largely unaddressed, and these results indicate that the work of the above authors would provide a strong foundation for such research.

Relationships Among Model Variables

As expected, the six variables signficantly related to computer use also proved to be significantly inter-related. However, the sole predicted relationship was not supported. Perceived impact proved to be unrelated to both profession and cluster membership (i.e., job requirements). Three relationships uncovered were consistent with relationships suggested by previous authors. An interest in computers-computer literacy relationship was suggested by Pope (1985) and a computer literacy-computer experience relationship was implied by Carpenter (1986), and these were strongly supported in this research (these variables were components of the capability with computers factor). Likewise, the job requirements-computer literacy relationship suggested by Konar, Kraut and Wong (1986) is consistent with the relationships found between capability with computers and both cluster membership and profession.

Consistent differences were found among professions and clusters. Members of the methodologist cluster group, who had significantly greater computer use, also had greater capability with computers and larger support systems. Among professions, computer scientists had larger support systems and greater capability with computers than other professions, while mathematicians had greater computer use. Computer scientists had the second highest computer use and mathematicians had the second highest capability with computers and support system size, although differences between these groups and other professions were not statistically significant. The distinctiveness of mathematicians and computer scientists is consistent with the nature of their scientific work. Scientific investigation for these groups typically involved programming of complex simulations, with little traditional data collection.

The Linear Prediction of Use

The results of this study indicate that a large portion of the variance in scientists' computer use can be accounted for by a limited set of variables. A stepwise regression of computer use on the six variables signficantly related to use, using the method of backward elimination to determine the order of variable entry, resulted in a two variable linear model, in which profession and cluster membership accounted for 58 percent of the variance in scientists' computer use.

Due to the high correlations among several model variables (e.g., capability with computers and support system size) a hierarchical regression analysis was also performed. Variables were divided into three groups or sets for entry into the regression equation based on a priori variable groupings, variable inter-relationships, and relationships to computer use. The order of variable set entry was based on causal priorities derived both logically and from the findings of this research. Variable set A (profession and cluster membership) was entered into the equation first, followed by variable set B (capability with computers and support system size), and then by variable set C (perceived impact and the importance of computer literacy and skills to colleagues). This regression analysis resulted in a two set (four variable) linear model of set A (profession, cluster membership) and set B (capability with computers, support system size) accounting for 62 percent of the variance in scientists' computer use. However, while the additional variance accounted for by the addition of set B to the regression equation was statistically significant, the partial and part correlations for set B were not significant. Therefore, caution must be exercised in interpreting this linear model. While the variables in set B may contribute slightly to the linear prediction of use, the contribution is clearly small. Overall, the results of both regression analyses strongly strong support those authors who have suggested various nature of work variables as determinants of computer use (e.g., Pope, 1985, whose findings suggest work activities and Collopy, 1988, whose findings suggest job categories).

Future Research

The results of this investigation clearly indicate that computer use varies considerably across scientists within an organization, and thus expectations of relatively widespread high use are inappropriate. These findings indicate that the potential exists to develop relatively accurate expectations regarding individual scientist's computer use (and by extension organizational use) based on the measurement of a limited set of variables. In order to effectively direct and allocate computer support and resources, and thus to impact scientists' use, continued work towards a more robust descriptive model of use is essential.

Considerable research remains to be done to explain the complex network of relationships between model variables. The results of this investigation suggest at least three tiers of variables in this network, where tiers reflect variable causal priorities. The first tier includes the two nature of work variables (e.g., profession and cluster membership). These variables reflect factors necessary for significant computer use (i.e, there must be a work need to expect significant levels of computer use). These variables probably directly influence scientists' level of computer use, but are unlikely to be influenced by use. The second variable tier includes support system size and capability with computers. These variables appear to both affect and be affected by scientists' computer use. The third tier of variables includes perceived impact and the importance of computer literacy and skills to colleagues. These variables appear to be only indirectly related to use, and are unrelated to the first tier of variables.

There are at least three areas that should be explored in an attempt to increase the variance accounted for in scientists' use. First, continued development of study variable measures is needed. Possible areas of improvement include development of a measure of perceived impact with a relative rather than an absolute scale, development of more and better measures of support system characteristics, further exploration of the characteristics that distinguish scientific professions, and development of a more direct measure of scientists' research cycles. Second, additional variables should be explored. Logical candidates include measures of technology characteristics (i.e., ease of use factors), as well as additional nature of work, individual difference, and organizational environment variables (Table 1 lists several candidates). Finally, the temporal nature of use should be explored. It appears that scientists' research cycle is a major determinant of computer use, suggesting that individual's use varies considerably over time. With the development of an effective measure of the research cycle it may be possible to predict changes in use over time, and thereby greatly enhance the accuracy of individual prediction and the organizational utility of both predictive and descriptive models. Explorations of the temporal nature of computer use might eventually be extended to examine the transition from implementation to an environment in which use is routine, thereby allowing the integration of models of implementation success with models of use in an environment where the technology is fully integrated.

These results are derived from a single organization. There is clearly a need to explore the robustness of the descriptive model across organizations and other population samples. The clarity of the relationships uncovered suggests that a fairly robust descriptive model can eventually be derived. Such a model could serve as a starting point for developing predictive models tailored to individual organizations. The descriptive model could contribute to the formulation of limited support systems directed toward factors that impact use, and the predictive model could be used to identify users in need of support. Finally, the study models are built upon current use, which might not in practice reflect desired use (i.e., all use may not equate to productive use). This suggests a need for further study of the use construct with a focus on whether non-productive use can be isolated and separately measured.

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Appendix A: Study Questionnaire

A: Demographics

Name ______________________________ Age _____

Highest Educational Degree ________________ Year obtained 19___

Discipline/Profession (e.g., chemist, physicist, etc.)

-> Originally ______________ -> Currently ________________

Years with IBM ______ Years at Research ______

Major Area(s) of Research:

____

____

B: Job Activities

Instructions for filling in the columns on the next page.

(1) Cross out the activities you perform, on average, *less than* 1 hour/week.

For the remaining activities:

(2) Hours/Week: ***estimate*** how many hours per week, on average, you spend on each activity.

(3) Importance: ***RATE*** the importance of each activity for successfully performing your job.

Use the following scale:

1 - extremely important
2 - very important
3 - moderately important
4 - somewhat important
5 - not at all important

Hours/ Week	Importance	
______	______	***Administrative: business activities or work management.*** Business/administrative (non-science) aspects of your job. Managing your work. Examples: a calendar, expense reports, handling MAIL, making reservations, reviewing posters, etc.
______	______	***Review: previous research.*** All activities involved in reviewing previous research. Examples: literature search, ordering articles, contacting authors to discuss their work, etc.
______	______	***Ideas: develop, propose or sell your research ideas.*** All activities involved in developing your research ideas, including proposing and selling them to others. Examples: proposal writing, discussing ideas with others, etc.
______	______	***Methods: develop methods, including tools, procedures, etc.*** All activities involved in preparing to conduct research. Examples, preparing lab equipment, developing a research procedure, writing programs to run an experiment, etc.
______	______	***Theoretical/analytical work.*** Develop theorems, proofs, theory, equations, etc. Examples: brainstorm on impacts of equation changes, write proofs, contemplate theory, review equations with colleagues.
______	______	***Generate or collect data.*** Any activity involving data generation or collection. Examples: running a program that generates data, running an experiment to obtain data, etc.
______	______	***Data analysis or interpretation (including visualization)*** Any activity involved in data analysis or interpretation, including visualization/graphics. Examples: running a data analysis program, coding data, using a graphics package to examine results, discussions about the meaning of an analysis.
______	______	***Communicate your research, including papers, reports, etc.*** Any activity involving communicating your research to others. Examples: writing papers and presentations, giving presentations, talking with colleagues about your findings, preparing technical reports.
______	______	***Supervisory activities.*** Any managerial or supervisory activity. Examples: performance reviews advising/directing subordinates' work, group/department planning work, budget related activities, etc.
______	______	***Help: obtaining or providing information or assistance.*** Obtaining or providing information or assistance of any kind. Examples: acting as a consultant, asking a colleague how to fix a problem, calling the computer center help desk, reading or responding to a conference disk forum question.
______	______	***Professional: educational activities, societies, etc.*** Any activity undertaken due to your professional status. Examples: taking an education course, doing work for a professional society, attending a conference and making contacts, etc. (*Note 20 days at conferences per year equals 1 hour per week*)
______	______	***Other - describe in the space below.***

C: Systems

(2) Instructions: **For those activities you use a computer for indicate your:**

(a) **Primary System:** The system you use most often to perform an activity

(b) **Secondary System:** If you use a second system list it also

System codes:
VM - the VM operating system
MVS - the MVS operating system
PC - a personal computer/workstation (*do not count use as a terminal*)
OT - other (explain) ____________________

Primary System | Secondary System

_____ _____ ***Administrative: business activities or work management.***
Business/administrative (non-science) aspects of your job. Managing your work. Examples: a calendar, expense reports, handling MAIL, making reservations, reviewing posters, etc.

_____ _____ ***Review: previous research.***
All activities involved in reviewing previous research. Examples: literature search, ordering articles, contacting authors to discuss their work, etc.

_____ _____ ***Ideas: develop, propose or sell your research ideas.***
All activities involved in developing your research ideas, including proposing and selling them to others. Examples: proposal writing, discussing ideas with others, etc.

_____ _____ ***Methods: develop methods, including tools, procedures, etc.***
All activities involved in preparing to conduct research. Examples, preparing lab equipment, developing a research procedure, writing programs to run an experiment, etc.

_____ _____ ***Theoretical/analytical work.***
Develop theorems, proofs, theory, equations, etc. Examples: brainstorm on impacts of equation changes, write proofs, contemplate theory, review equations with colleagues.

_____ _____ ***Generate or collect data.***
Any activity involving data generation or collection. Examples: running a program that generates data, running an experiment to obtain data, etc.

_____ _____ ***Data analysis or interpretation (including visualization)***
Any activity involved in data analysis or interpretation, including visualization/graphics. Examples: running a data analysis program, coding data, using a graphics package to examine results, discussions about the meaning of an analysis.

_____ _____ ***Communicate your research, including papers, reports, etc.***
Any activity involving communicating your research to others. Examples: writing papers and presentations, giving presentations, talking with colleagues about your findings, preparing technical reports.

_____ _____ ***Supervisory activities.***
Any managerial or supervisory activity. Examples: performance reviews advising/directing subordinates' work, group/department planning work, budget related activities, etc.

(Question continued on next page)

(Question continued from previous page)

_____ _____ ***Help: obtaining or providing information or assistance.***
Obtaining or providing information or assistance of any kind. Examples: acting as a consultant, asking a colleague how to fix a problem, calling the computer center help desk, reading or responding to a conference disk forum question.

_____ _____ ***Professional: educational activities, societies, etc.***
Any activity undertaken due to your professional status. Examples: taking an education course, doing work for a professional society, attending a conference and making contacts, etc.

_____ _____ ***Other - describe in the space below.***

D: Computing Experience

(1) Compared to all other scientists at Yorktown (excluding computer science), how much experience would you estimate you have with computers?
(Circle One)

Much More	More	About Average	Less	Much Less
1	2	3	4	5

(2) How many years have you been using computers in your work (including non-IBM years)?

_____year(s)

(3) On average, how many *of your work hours per week* do you spend in front of a computer *actively using it*?

_____ hours/week

(4) Rate your familiarity with computer technology. For example, how familiar are you with the potential uses of computing, likely future developments, the marketplace, and differences in capabilities of various systems.
(Circle One)

Very High	High	Moderate	Low	Very Low
1	2	3	4	5

(5) Rate your overall computer skills. Consider, for example, (a) your skills at using on-line services for communications and administrative tasks, (b) your skills using a variety of software packages, and (c) your programming skills.
(Circle One)

Very Good	Good	Fair	Poor	Very Poor
1	2	3	4	5

(6) Rate your level of knowledge and understanding of the technical workings of computers. Someone very low in knowledge might, for example, know the basic components of a system, such as memory, input, output, etc. While someone very high in knowledge might understand how a system works at a detailed internal level.
(Circle One)

Very High	High	Moderate	Low	Very Low
1	2	3	4	5

E: Current Status

(1) How satisfied are you with your current hardware and software for accomplishing your work?
(Circle One)

Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
1	2	3	4	5

F: Computing Environment

(1) Rate your level of interest in computing, compared to other scientists at Yorktown. Consider such things as how often you try new hardware and software and how much time you spend discussing and reviewing computing-related issues.
(Circle One)

Very High	High	Average	Low	Very Low
1	2	3	4	5

(2) How much importance do your colleagues place on computer literacy and computer skills?
(Circle One)

Extremely Imp.	Very Imp.	Moderately Imp.	Slightly Imp.	Not Imp.
1	2	3	4	5

(3) How much importance does your management place on computer literacy and computer skills?
(Circle One)

Extremely Imp.	Very Imp.	Moderately Imp.	Slightly Imp.	Not Imp.
1	2	3	4	5

G: Support System

(3) Indicate about how often you are in contact with each computing information source to exchange computing-related information.

Use the following scale:

1 - At least once per day
2 - 2 or 3 times per week
3 - 2 or 3 times per month
4 - 3 or 4 times per year
5 - once or twice a year or less

Number of Contacts

______ Support materials (manuals, on-line help, etc.)

______ Journals and magazines

______ Consultants/systems staff (in person, phone, on-line, etc.)

______ Forum/conference disks

______ Colleagues within your work group

______ Others at Yorktown

______ Non-Yorktown individuals (including non-IBMers)

______ Other (explain) ______________________

(5) With approximately how many people do you discuss or exchange *computing-related information* on a somewhat regular basis?
(circle one)

1	2	3	4	5
0-2 people	3-5 people	6-8 people	9-11 people	12 or more

H: Impact of Computing

(1) RATE the overall effect of your use of computers on the following aspects of your job.
Use the following scale
1 - Strong positive effect
2 - Slight positive effect
3 - No significant effect
4 - Slight negative effect
5 - Strong negative effect

Rating

______ Overall Productivity

Autobiographical Statement

The author was born December 17, 1961 in Kalamazoo, Michigan. He received his Bachelor of Arts degree with majors in economics & business administration, and psychology, from Kalamazoo College in June, 1984, and his Masters of Science degree in psychology from Old Dominion University in December, 1986. Following various appointments as a research assistant while in graduate school, including an extended period with the Naval Training Systems Center, the author interned during the fall of 1987 with the Corporate Human Factors group at Digital Equipment Corporation in Maynard, Massachusetts. The author next worked for 18 months as a Research Supplemental employee at the IBM T. J. Watson Research Center in Yorktown Heights, New York. This dissertation was performed while serving that appointment. The author currently works for the Federal Sector Division of IBM in Rockville, Maryland. He functions as the lead engineer in the design and development of the computer-human interface for the tower control computer complex portion of the IBM and Federal Aviation Administration Advanced Automation System (AAS) project. The AAS project involves the design and development of a modernized United States air traffic control system.