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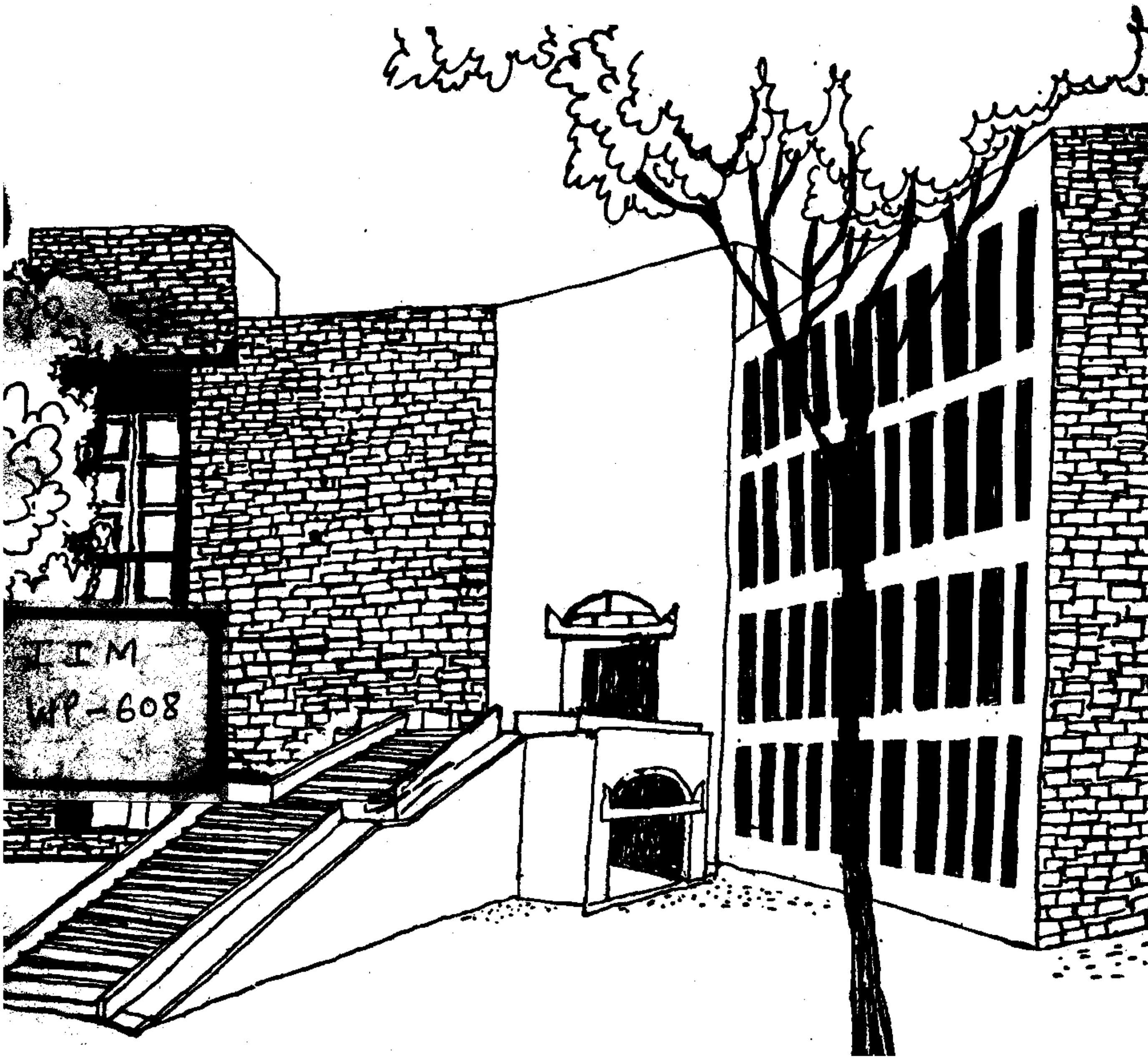

EXPECTED PERFORMANCE IN HUMAN/COMPUTER APPLICATIONS AS A FUNCTION OF USER PROFICIENCY AND SYSTEM POWER

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Expected Performance in Human/Computer Applications as a Function of User Proficiency and System Power

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Abstract

Managers and students of management in India predicted performance in human/computer systems from information about the user's proficiency with computers and the power of the system. User proficiency was defined as the user's ability to work with computers; and system power was defined as the computer's ability to store, retrieve, and analyze data. Five different models were proposed for how user proficiency and system power are expected to determine performance. These were (a) a matching model in which optimal performance is achieved when the power of the system is judged to be compatible with the proficiency of the user, (b) an averaging model in which expected performance is the average of the values of user proficiency and system power, (c) a multiplying model in which performance is the product of the values of user proficiency and system power, (d) a human/computer ratio model in which performance is determined by the ratio of system power over total effort, and (e) a computer/human ratio model in which performance is determined by the ratio of user proficiency over total effort. Participants rated 16 combinations of user proficiency and system power from a 4 X 4 factorial design. The pattern of ratings indicated that 51 percent used a multiplying model and 25 percent used an averaging model; whereas, only 6 percent used the matching model and 4 percent used a ratio model. The remaining 14 percent did not follow any model clearly. Implications of these results were discussed for the design of the human/computer interface, training and selection of users, and the cost-benefit trade-offs for investment in user training versus equipment acquisition.

Managers deciding whether to computerize a task must make assessments as to whether the combination of the people using computers will lead to improved performance over people not using computers. Much been written on the factors involved in the decision to computerize (e.g., Dolotta, et al., 1976; Rothery, 1971; Simon, 1960). The factors involved in such decisions usually include the level of computer power needed and the technical skills required of the users. Any assessment of the utility of the computer and its effect on performance depends on the power of the system and the ability of the users. Developing more powerful systems has been the primary concern of industry. However, the selection and training of computer users has also been emphasized as a critical factor (Mayer, 1970). Although both factors are important, it is not clear which factor is perceived to be of greater importance, nor is it clear how they are expected to combine to produce overall performance.

A number of ideas as to how user proficiency and system power interact in determining performance of systems have been expressed in the literature. On the one side, proponents of computerization have emphasized the power of the computer to solve problems and the limitations imposed by unskilled users. For example, Licklider (1960) discusses the idea of a "man-machine symbiosis" and defines it as the close cooperation between the user and the computer in which the user sets goals, formulates hypotheses and models, asks questions, defines criteria and procedures, and the computer tests models, answers questions, carries out procedures, and displays the results. Licklider then identifies obstacles to this symbiotic relationship such as the inability of the user to formulate hypotheses and questions and the difficulty with language problems.

Others have proposed a more synergistic relationship in which overall performance is greater than the sum of the parts contributed by the human and by the computer. It is assumed that there exists some unique combination of the two such that the power of the system and the performance of the user are enhanced by each other. Dehning, Essig, and Maass (1981), for example, distinguish between "objective operating complexity" which is the actual complexity given by a system and "subjective operating complexity" which is the user's perception of the operating complexity that he has to overcome. In their view, "...an optimal man-computer interface design can be regarded as an optimization problem between a maximal flexibility of use and a minimal operating complexity" (p. 6). If system power is synonymous with objective operating complexity and user proficiency is inversely related to subjective operating complexity, then for any level of user proficiency there should be an optimal level of system power.

On the other hand, quite a different idea is expressed by Nelson (1970) in discussing the management of programming. He considers the factors of manpower output and equipment output. On the basis of the idea of marginal productivity, he assumes a substitution function between manpower output and equipment output. For a constant level of productivity, the slope of the function is the substitution ratio between the two factors. If user proficiency is directly related to manpower output and equipment output is a direct function of system power, then performance should be equal to the product of system power and user proficiency.

Views such as these have for the most part been the theoretical conjectures and little is known about actual assessments by those who make decisions about computer implementation. This study was intended to determine the underlying assumptions about how user proficiency and system power are expected combine to produce performance.

Models of Man/Machine Performance

In order to sharpen the contrasting views and to explore additional ideas, five alternative models are proposed that specify algebraic functions for the integration of information about user proficiency and system power. In each case, the function results in a specific pattern of expected performance as a function of levels of user proficiency and system power. These patterns served as point of reference for the analysis of behavioral data.

__Matching model__. If the computer is viewed as a tool, one might assume that there should be at some level a match between the user skill and tool complexity. A user of low proficiency will perform best with a simple tool and a user of high proficiency will perform optimally with a more powerful tool that matches his or her ability. Thus, optimal performance is expected when there is a perceived match between user proficiency and system power as suggested by Dehning, et al. (1981). The first panel of Figure 1 shows the predicted pattern for this model when each level of user proficiency matches the corresponding level of system power. Furthermore, this model may be expressed in the following equation:

$$P = (H + C)/2 \qquad \text{when } H \geq C > 0, \tag{1a}$$

$$P = H - (C - H)/2 \qquad \text{when } C > H > 0, \tag{1b}$$

where $\underline{P}$ is expected performance, $\underline{H}$ is the assessed level of user proficiency, and $\underline{C}$ is the assessed level of system power. The precise weighting of the two factors and their judged equality will depend on the opinion of the individual and will deviate from Equation 1. However, the unique form of the data remains constant in that performance increases with system power up to a maximum and then decreases as system power surpasses user proficiency.

Insert Figure 1 about here

__Averaging model__. A symbiotic relationship may be assumed in which expected performance is the average of user proficiency and system power. In this model, there is no interactive effect between the levels of user proficiency and system power. The two work together but one does not enhance or limit the effect of the other on performance. The averaging model is compensatory in that a deficit in one factor can be made up for by a credit in the other factor. For example, a proficient user may compensate for limited system power by using the system more effectively. On the other side, a powerful system may compensate for low user proficiency with online-help and menu selection. The second panel in Figure 1 shows the pattern of expected performance for the averaging formulation. Parallel lines are observed since the effect of each factor is the same for all levels of the other factor. Furthermore, this model may be expressed in the following equation:

$$P = (H + C)/2 \qquad \text{for all } H \text{ and } C > 0, \tag{2}$$

Again the exact form of Equation 2 may vary depending on the weighting of the two factors. Although averaging has not been suggested as a model for human/computer interaction in the past, it has received support in a number of information integration tasks (Anderson, 1981).

<u>Multiplying model</u>. A synergistic formulation may assume that combined performance is equal to the product of the levels of user proficiency and system power. In this case, the effect of system power is enhanced by increased user proficiency. The proficient user is able to gain higher performance with powerful systems. On the other hand, increased system power is of little effect when the user is of low proficiency. The multiplying model is characterized by a diverging fan of lines as shown in the third panel of Figure 1. The multiplying model may also be expressed as a geometric average as shown in the following equation:

$$P = (H * C)^{1/2} \qquad \text{for all } H \text{ and } C > 0. \tag{3}$$

This model implies that if either user proficiency or system power is very low, it nullifies the effect of the other factor. Furthermore, the effect of each factor is proportional to the level of the other factor. The multiplying model was suggested by Nelson (1970) and has received support in other tasks where subjects have made judgments about overall systems (e.g., Norman & Louviere, 1974).

Human/computer ratio model. Another interesting possibility is a ratio model in which expected performance is determined by the contribution of one factor relative to the whole. The ratio model has been used to describe the relationship between inputs and outputs in equitable economic situations (Anderson, 1981; Leon & Anderson, 1974). In the case of human/computer interaction, performance (or system output) is the ratio of user proficiency over the total effort expended. The fourth panel of Figure 1 shows the pattern produced by this model, and the following equation expresses it mathematically:

$$P = H / (H + C') \qquad \text{for all } H \text{ and } C' > 0, \tag{4}$$

where $C' = 1/C$ so as to preserve the direction of the effect of system power. The result is that for a user of either very low or very high proficiency, system power has only a small positive effect. In the intermediate range, however, system power has a substantial effect. The idea is that for a user of low proficiency, increases in system power will have little or no impact. At the other extreme, highly proficient users are already performing at such a high level that increased system power again shows only a small effect. An application where this sort of pattern might occur is with an expert knowledge system. An expert in the knowledge domain using the system will perform nearly as well with or without increases in system power. It is in the middle range that a user will benefit from the computer. The computer in this model is an aid. The first step is to gain enough proficiency to use the computer; the second step is to gain proficiency in the knowledge domain so that the person can perform without the help of the computer. Both expert knowledge systems and computer assisted instruction may fit this model.

Computer/human ratio model. As a compliment to the last model, performance may be determined by the ratio of user proficiency over total effort as expressed in the following equation:

$$P = C \,/\, (H' + C) \qquad \text{for all } H' \text{ and } C > 0, \tag{5}$$

where $H' = 1/H$ so as to preserve the direction of effect of user proficiency. The fifth panel of Figure 1 shows the pattern for this model. The result is that for a system of very low power or of very high power, user proficiency has only a small effect. In the intermediate range of system power, user proficiency has a substantial effect. A computer of very low power will result in low performance for all users. Low computer power limits performance. At the other extreme, for a system of very high power, user proficiency will not matter. The machine is not limited by the low proficiency of the user. Systems using natural language comprehension, menu selection, and artificial intelligence techniques may provide examples of this model.

An Empirical Study

In order to ascertain the prevailing model for assessing optimal performance, participants were shown a series of scenarios in which combinations of user proficiency and system power were described. The methodology of information integration theory was used in order to design the materials and to determine the best fitting model (Anderson, 1982; Norman, 1981). In addition to the information integration task, two questionnaires were administered to characterize participants' knowledge and attitudes about computers and their beliefs about how user proficiency and system power combine to determine performance.

Method

Participants. Two groups participated in this study. First, a group of eighteen managers from thoughout India participated in this study as part of a one week workshop on the use of computers in management. The workshop was conducted at the Management Development Center of the Indian Institute of Management, Ahmedabad. Most of the managers had prior experience with computers. Second, a group of 33 students in the post graduate program at the Indian Institute of Management, Ahmedabad volunteered to participate. The post graduate program is equivalent to the MBA degree. Nearly all of the students had also had exposure to the use of computers in their coursework. All of the managers and all but one of the students were male.

Procedure. Three questionnaires were distributed to the participants and they were asked to complete them in the order given. The first questionnaire included (a) 6 yes/no items on prior experience with computers, (b) 4 items in which self-assessment of knowledge about computers was rated on a 5-point scale, and (c) 12 items in which agreement/disagreement with statements about computers was rated on a 5-point scale. These items are listed in Tables 1 and 2.

In the second questionnaire (the information integration task), participants were asked to consider a manager in charge of project development who needs to retrieve and analyze information from a computerized data base in order to make decisions about company strategy. They were asked to judge the performance of such systems on the basis of the proficiency of individuals using the system and the power of the system. The scenarios used for these ratings are described below.

The third questionnaire included (a) one item in which participants indicated which factor was of greater importance in determining performance and (b) 7 items in which agreement/disagreement with statements about the power of computers and user proficiency was rated on a 5-point scale. These last 7 items are listed in Table 4.

Managers completed ratings at their leisure and the booklets were collected the following day. The group of students completed their ratings in a lecture hall. They took from 20 to 35 minutes to complete all three questionnaires.

Materials for scenarios. Scenarios describing combinations of user proficiency and system power were generated using a 4 x 4 factorial design. Four levels of user proficiency were described as not at all proficient using computers, somewhat proficient using computers, moderately proficient using computers, and highly proficient using computers. Four levels of system power were described as not very powerful, moderately powerful, very powerful, and extremely powerful. In addition to the 16 scenarios generated from the factorial design, 4 representative practice scenarios also were generated. The scenarios were presented in booklets in a random order with the practice items first, then two replications of the scenarios. Four scenarios appeared on each page. The pages were stapled in a different random order for each participant. Instructions appeared on the first page of the booklet. Just below each combination of a person and system appeared a 100 mm rating scale on which participants made a vertical mark to indicate expected performance. The left extreme of the scale was labeled very low performance and the right extreme was labeled very high performance.

Results

Prior Exposure to and Knowledge about Computers

Prior to the workshop on personal computers, only 28 percent of the managers had used a computer. Of the students, 97 percent had used a computer before. Table 1 lists the proportions of participants that answered affirmatively to the questions about prior exposure. Students reported much more experience with computers than did managers. Table 1 also lists the mean ratings of amount of knowledge about various aspects of computers. Although the students gave slightly higher mean ratings, no significant differences were detected between the managers and the students.

Insert Table 1 about here

Table 2 lists the mean ratings of agreement/disagreement with statements about computers. Again there was little difference between the managers and the students. Only one significant difference occurred. Managers expressed a higher agreement than did students with the statement that managers in India should learn more about computers. Over both groups significant agreement or disagreement was expressed with all but three statements. Participants were ambivalent about the statements (a) that the computers will replace people, (b) that computers tend to dehumanize the workplace, and (c) that India should encourage the import of computers. The statements that were most agreed with were (a) the desire to learn more about computers, (b) the need for managers to learn more about computers, and (c) the need for computers in business. The one statement disagreed with was that businesses in India could manage without computers.

Insert Table 2 about here

<u>Overall Analysis of Expected Performance</u>

In this section the results of the group rating data will be presented. The top panel of Figure 2 shows the mean rated performance as a function of system power and user proficiency for the group of managers, and the bottom panel shows these data for the group of students. It can be seen in both cases that ratings tend to increase with system power as shown by the positive slopes of the lines and with user proficiency as shown by the increased height of the lines. However, when the user was described as being "not at all proficient," ratings did not increase substantially with system power.

Increases in system power had their greatest effect when users were described as being highly proficient. It is also interesting to note that participants judged the descriptions moderately proficient and somewhat proficient as having nearly the same value.

Both the main effects of system power and user proficiency were significant for both groups (managers: $F(3,54) = 18.96$ for system power and $F(3,54) = 177.17$ for user proficiency; students: $F(3,96) = 48.23$ for system power and $F(3,96) = 206.51$ for user proficiency, $p < .001$ in each case). For the levels of user proficiency and system power described in scenarios, user proficiency had a much greater effect on expected performance than system power for both the managers and the students. Furthermore, in the individual-subject analyses of variance, 76% of the participants showed a greater effect for user proficiency than for system power.

Insert Figure 2 about here

Significant interactions were found in both groups between system power and user proficiency (managers: $F(9,153) = 9.77$; students: $F(9,288) = 15.50$ $p < .001$ in each case). In both groups, there was a diverging pattern indicating that system power has a greater effect for highly proficient users than for users with low proficiency. However, the group results display an aggregate pattern and are not necessarily representative of individuals composing the groups. Consequently, individual data were analyzed in terms of the five proposed models.

Individual Model Analysis

Each of the five proposed models is characterized by a unique interaction pattern. The simplest is the averaging model which predicts a zero interaction between the factors and is exemplified by parallel lines. The rest of the models are characterized by the presence of particular interaction components when orthogonal polynomial coefficients are used to generate contrasts. The matching model predicts large Linear x Linear, Quadratic x Quadratic, and Cubic x Cubic components relative to other components. The multiplying model predicts a large Linear x Linear component relative to other components. The human/computer ratio model predicts a large Linear x Quadratic component. Finally, the computer/human ratio model predicts a a large Quadratic x Linear component.

In order to characterize each participant's data as conforming to one of the five models, interaction components were estimated for each subject. Significance tests per se were not conducted since the intent here was not to reject a null hypothesis but rather to select the most likely of the alternative models. First, the F-ratios for the overall 4 x 4 interaction were calculated for each participant. If the F-ratio was less than 1.0 participants were classified by the averaging model. Of the 18 managers, 5 were classified by the averaging model; and of the 33 students, 8 were classified by the averaging model. For the remainder of the participants, four F-ratios corresponding to four of the models were calculated as follows:

Matching Model: $$F(3,6) = ((SS_{LL}+SS_{QQ}+SS_{CC})/3) / (SS_{Residual}/6), \quad (6)$$

Multiplying Model: $$F(1,8) = SS_{LL} / (SS_{Residual}/8), \quad (7)$$

Human Ratio Model: $$F(1,8) = SS_{LQ} / SS_{Residual}/8), \quad (8)$$

Computer Ratio Model: $$F(1,8) = SS_{QL} / SS_{Residual}/8), \quad (9)$$

where $SS_{Residual}$ is the $SS_{Interaction}$ minus the component sums of squares listed in the numerator of each equation. If one of these terms was significant, a participant was assigned to that model. If two or more were significant, the participant was assigned to the one having the largest effect. Finally, if none were significant, then the participant was not assigned to any model.

Table 3 displays the results of this analysis. It can be seen that the most predominant pattern is the multiplying model with 51% of the participants characterized by this model. The averaging model was second with 25% and the numbers assigned to other models were negliable. Nearly 14% were not classified using the procedure described above. However, visual inspection of the graphs of these participants indicated that all but one of the patterns were close to the averaging pattern.

Insert Table 3 about here

Figure 3 shows the factorial graphs of the mean ratings of participants classified into the averaging and multiplying patterns. The characteristic diverging fan pattern can be seen in the bottom panel of Figure 3 for participants classified by the multiplying model. The lines are more parallel in the top panel of Figure 3, but the diverging fan pattern is still evident.

Insert Figure 3 about here

Follow-Up Questionnaire

All of the managers and all but one of the students indicated that the ability of the individual was of greater importance than the power of the computer. Table 4 shows the results of the rest of the questions pertaining to the rule by which user proficiency and system power combine to determine performance. Managers and students differed on three points. Managers agreed to a higher extent than did students with the idea that optimal performance is only achieved when there is a match between the ability of the individual and the power of the computer. Also managers rated higher agreement with both the averaging and multiplying formulations than did students as indicated by the last two items in Table 4. Overall, it is interesting to note that both managers and students expressed more agreement with the idea that the power of the computer is limited by the ability of users than with the converse that the performance of user is limited by the power of the computer.

The results in Table 4 can also be compared with the results of the individual analyses. Overall, there was a significant disagreement with the averaging rule and agreement with the multiplying rule. This is consistent with the predominance of the multiplying model in the rating task. Also consistent with the multiplying model was the disagreement with the idea that computer power can compensate for lack of ability on the part of the user. The one anomaly is that both students and especially managers rated high agreement with the idea that optimal performance is only achieved when there is a match between the ability of the individual and the power of the computer. The matching model was not evidenced in the rating results.

Insert Table 4 about here

Discussion

Although obvious to most, it is a profound statement to some that while people can work without computers, computers do not work without people. It is the interaction of people using computers that determines the overall performance of systems. However, little has been known about the presumed function by which people and computers are believed to produce performance. Consequently, this study investigated the way in which managers and students of management predict performance as a function of user proficiency and system power. The results of this study have a number of implications for the design and management of human/computer interaction, the selection and training of users, and future enhancements in computer power.

User Development vs. System Enhancement

Although in the past enhancing computer power may have been of more concern than developing user ability, the present data clearly attest to a reversed position on the part of managers and students of management. In the assessment of scenarios, the factor of user proficiency had a much greater effect than did system power. One explanation is that the perceived range of computer power was not perceived to be as great as the range of user proficiency. In the current market of computers, even at the low end of computer power, the computer may be capable of much. Thus, a computer described as "not very powerful" may very well be perceived as being quite adequate to meet one's needs. On the other hand, the manager is more familiar with the wide range of human capability and lack thereof. At the low end of user proficiency, a person described as being "not at all proficient using computers" would probably be perceived as less than adequate. Irregardless of whether the effect is due to a greater concern for users or a greater range of values, the overall result is that the emphasis is on user proficiency rather than on computer power. The implication is that managers are more sensitive to the need for user selection and training than for enhancing computer capabilities.

A Model of Human/Computer Interaction

The judgments of managers and students of management strongly support the contention that performance is equal to the product of user proficiency and system power. This idea was expressed a number of years ago by Nelson (1970) in the form of a multiplicative substitution function between manpower output and equipment output. Although the data of some individuals followed the averaging rule, the majority showed the characteristic multiplying pattern.

Both the multiplying and the averaging models assert that optimal performance is achieved when both user proficiency and system power are at a maximum. Furthermore, increases in either factor will result in higher expected performance. This is in direct conflict with the matching model which asserts that optimal performance is achieved only when there is a match between user ability and computer power. High levels of system power did not result in decreased assessments of performance even when system power was well beyond the level of user proficiency. It is curious that the matching model received so little support despite its seeming plausibility in the human factors literature (e.g., Dehning, et al., 1981). Even the participants in this study agreed with the concept of the matching model in the follow-up questionnaire. It is possible that the participants did not equate system power with the idea of "operating complexity." System power can be interpreted as processing speed or size of memory rather than complexity of the human/computer interface. But this is unlikely since the statement affirming the matching model that they agreed with in the follow-up questionnarie used the term "system power."

One way to reconcile the discrepancy between the judgment data and the follow-up questionnaire may be to assume that the multiplying model meets some minimal conditions of matching. Assume, for example, that there are only two functional levels of user proficiency. At the low end, for users described as not at all proficient, no increase in performance occurs with system power. A decrease does not occur because perfromance is already at a minimal level. However, when user proficiency has surpassed some minimal threshold, increases in system power have an effect. It appears then that in the view of managers and students of management that excess computer power does not lead to decreased performance. The implication is that one might as well buy a computer that surpasses the ability of the user as long as the performance of the user is above some minimal threshold.

The averaging model received some support in the judgment data despite the significant disagreement by the students with the statement that overall performance is the average of the ability of the individual and the power of the computer. However, within bounds, the averaging and multiplying models can be quite similar and hard to distinguish. Even those individuals classified by the averaging model show a slight diverging fan characteristic of the multiplying model.

The multiplying and averaging models agree only in that highest performance is expected when both factors are high and that lowest performance is expected when both factors are low. Differences emerge between the two models when one factor is high and the other is low. In practice this is the most frequent scenario that managers have to deal with. The implication of the averaging model is that benefits acrued by increasing either user proficiency or system power are the same no matter what the level of the other factor. The implication of the multiplying model is quite different. Increases in user proficiency have a greater impact when system power it high. Similarly, increases in system power have a greater impact when user proficiency is high. Consequently, it is the combination of high user proficiency and high system power that is most important. It also means that although managers may be more concerned about user proficiency, the effect of user proficiency on performance cannot be separated from system power.

Neither of the ratio models received support. It may be that scenarios exist in areas such as computer assisted instruction and expert knowledge systems where such ratio models are plausible. However, the scenario that was used in this study described a general information retrieval system. It is possible that with other scenarios, judgments of expected performance may follow different rules.

Generalizability and Cross-Cultural Issues

A final question pertains to the nature of the Indian context and the generalizability of these results to other contexts. First, it should be noted that these results are interesting in there own right in that India is one of the largest developing countries in the world and is on the verge of computerization. The expectations expressed by the participants in this study are probably more representative of the market leaders and up-and-coming managers in India rather than the attitudes of the vast majority of the population which are not attuned to the benefits of computerization. The results summarized in Table 2 attest to the positive attitudes of the managers and students toward computers. Consequently, these results may be limited to an elite group of managers and students. The results may be different with other populations such as system analysts, data processing workers, etc. However, managers were specifically chosen in the present case since it is this group that is fundamentally involved in decisions to computerize in both the public and private sectors and they are responsible for setting policies regarding computer acquisition and training of users.

Second, there are some interesting cross-cultural differences in the study of information integration between India and the U.S. in the way in which individuals combine information in some tasks. In the U.S. when students are asked to predict performance of an individual on the basis of information about ability and motivation, a multiplying model is generally found (e.g., Anderson, 1981; Anderson & Butzin, 1974). However, in a careful series of studies, Singh, Gupta, and Dalal (1974) and Singh and Bhargava (1985) were not able to replicate these results in India. Instead their results conformed to the pattern of the averaging model. Therefore, it has been suggested that in the India context human performance is judged in a more equalitarian manner such that motivation has the same impact on individuals of either low or high ability. The effect of either factor is equal no matter what the level of the other factor.

In the present case, the multiplying model was supported in India when judgments are made about the performance of human/computer systems. At present, it would seem that the averaging model in India is limited to judgments of human performance in exams (Singh & Bhargava, 1985); whereas, the multiplying model applies to judgments about expected performance in human/computer systems. Perhaps the cognitive algebra of expected performance is linked with the nature of the task as Singh and Bhargava have suggested.

In any case, the equalitarian notion of the averaging model with repcect to motivation and ability does not seem to hold in human/computer applications. For those with powerful computers, user proficiency will have a greater effect on performance than for those with not so powerful computers. And similarly, for those with proficient users, enhancements in system power will have a greater effect than for those without proficient users.

Author Notes

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Table 1

Prior Exposure to Computers and Self-Assessment of Knowledge about Computers

	Proportion answering "yes"	
Question	Managers (N-16)	Students (N-33)
Have you ever used a computer before?	.28	.97
Have you ever had a general course on computers?	.69	.91
Have you ever had a course on the use of computers in business?	.62	.82
Have you ever had a course on computer programing?	.50	.94
Have you ever had a course on computers as teaching aids?	.00	.10
Have you ever used a personal computer?	.06	.94

	Mean ratings of amount of knowledge[1]	
Type of Knowledge	Managers (N-16)	Students (N-33)
Computers in general	3.0 (1.2)	3.2 (0.9)
Use of computers in business and management	3.2 (1.0)	3.3 (0.9)
Use of computers in India	2.9 (1.0)	3.1 (0.9)
Development of computers in foreign countries	2.9 (1.1)	3.2 (1.2)

Notes:

[1] Ratings were made on a 5-point scale where 1 = "Very little knowledge" and 5 = "Very much knowledge."

Parenthesized values are standard deviations.

Table 2

Mean Ratings of Agreement/Disagreement with Statements about Computers

	Managers (N=16)	Students (N=33)	Weighted Average
Computers are becoming more and more necessary for business in India.	4.6 (0.6)	4.2 (0.9)	4.3 (0.8)**
Computers are solving many problems that people cannot.	3.9 (1.1)	4.1 (1.0)	4.0 (1.0)**
Computers will replace people in many jobs.	2.8 (1.2)	3.3 (1.1)	3.1 (1.1)
Computers will help people achieve their maximum potential.	4.3 (0.9)	3.9 (0.8)	4.0 (0.8)**
Computers will create many new jobs.	3.6 (1.2)	3.5 (1.2)	3.5 (1.2)**
Computers tend to dehumanize the work situation.	3.1 (1.4)	2.9 (1.2)	3.0 (1.3)
Businesses in India can manage quite well without computers.	2.0 (1.2)	2.3 (0.9)	2.2 (1.0)**
I would like to learn more about computers.	4.9 (0.3)	4.8 (0.5)	4.8 (0.4)**
Managers in India should learn about computers.	5.0 (0.0)	4.6 (0.5)**	4.7 (0.4)**
India should invest in self-reliance on computers.	3.6 (1.5)	3.9 (1.0)	3.8 (1.2)**
Only people can solve important problems.	3.6 (1.0)	3.7 (1.0)	3.7 (1.1)**
India should encourage the import of computers.	3.3 (1.2)	3.2 (1.1)	3.2 (1.1)

<u>Notes</u>:

Ratings were made on a 5-point scale where 1 = "Disagree" and 5 = "Agree."

Parenthesized values are standard deviations.

** $p < .01$

Table 3

Classification of Individuals by the Five Models

Model	Managers	Students	Total
Averaging Model	5	8	13
Matching Model	2	1	3
Multiplying Model	8	18	26
Human/Computer Ratio Model	1	1	2
Computer/Huamn Ratio Model	0	0	0
Not Classified	2	5	7
Total	18	33	51

Table 4

Mean Ratings of Agreement/Disagreement with Statements about User Proficiency and System Power

Statement	Managers (N=16)	Students (N=33)	Weighted Average
The power of the computer is limited by the ability of the user.	3.9 (1.4)	4.2 (0.9)**	4.1 (1.1)**
The performance of individuals is limited by the power of the computer.	3.2 (1.3)	3.1 (0.9)	3.1 (1.0)
Optimal performance is only achieved when there is a match between the ability of the individual and the power of the computer.	4.6 (0.8)	4.0 (1.2)	4.2 (1.1)**
Computer power can compensate for lack of ability on the part of the user.	2.5 (1.2)	2.2 (1.0)	2.3 (1.1)**
Extremely proficient users are able to overcome the limitations of the computer.	3.8 (1.0)	3.7 (1.0)	3.7 (1.0)**
Overall performance is the average of the ability of the individual and the power of the computer.	2.9 (1.2)	2.3 (0.9)	2.5 (1.0)**
Overall performance is the product of the ability of the individual and the power of the computer.	4.3 (1.1)	3.3 (1.2)**	3.6 (1.2)**

Notes:

Ratings were made on a 5-point scale where 1 = "Disagree" and 5 = "Agree."

Parenthesized values are standard deviations.

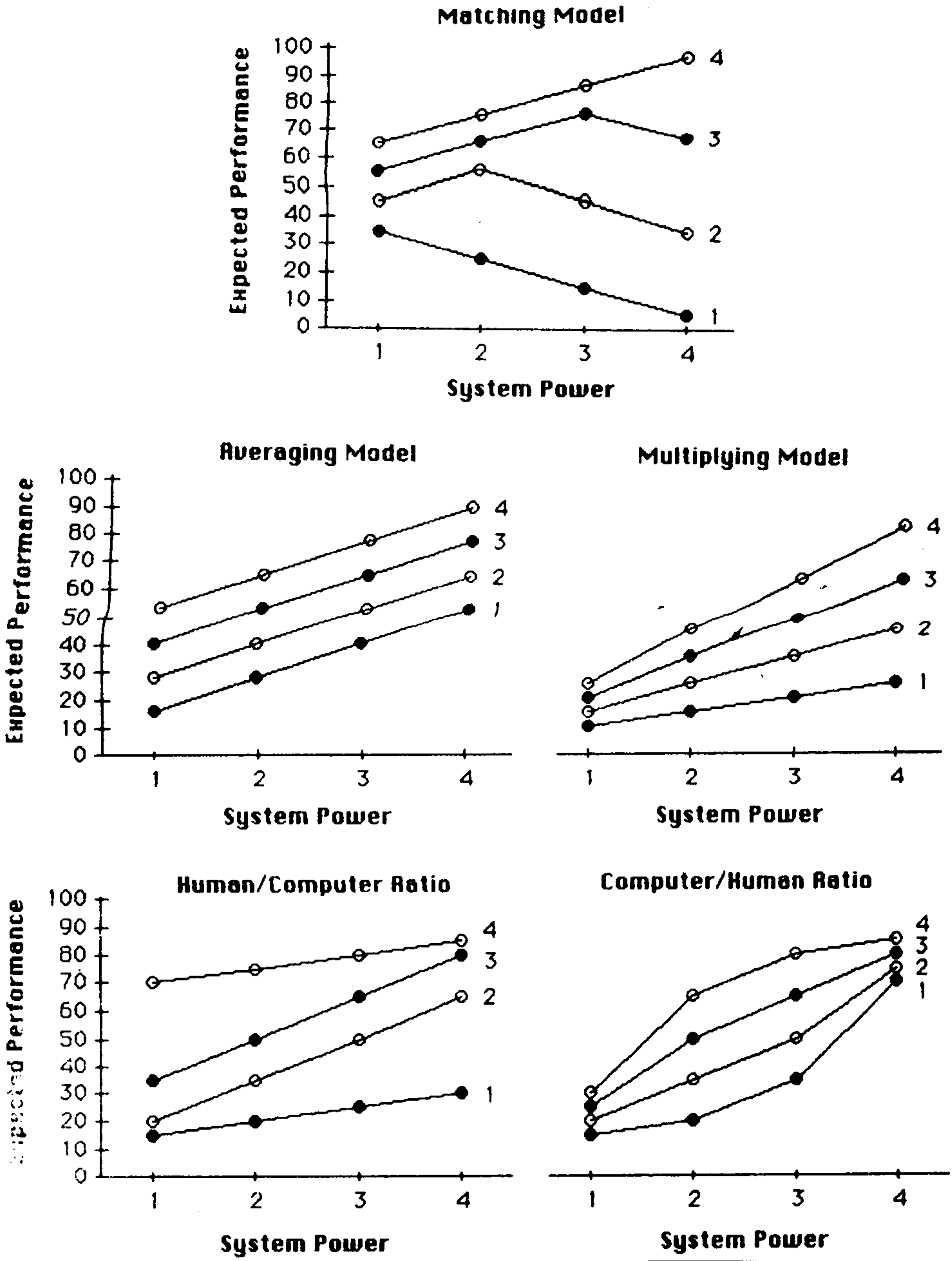
** $p < .01$

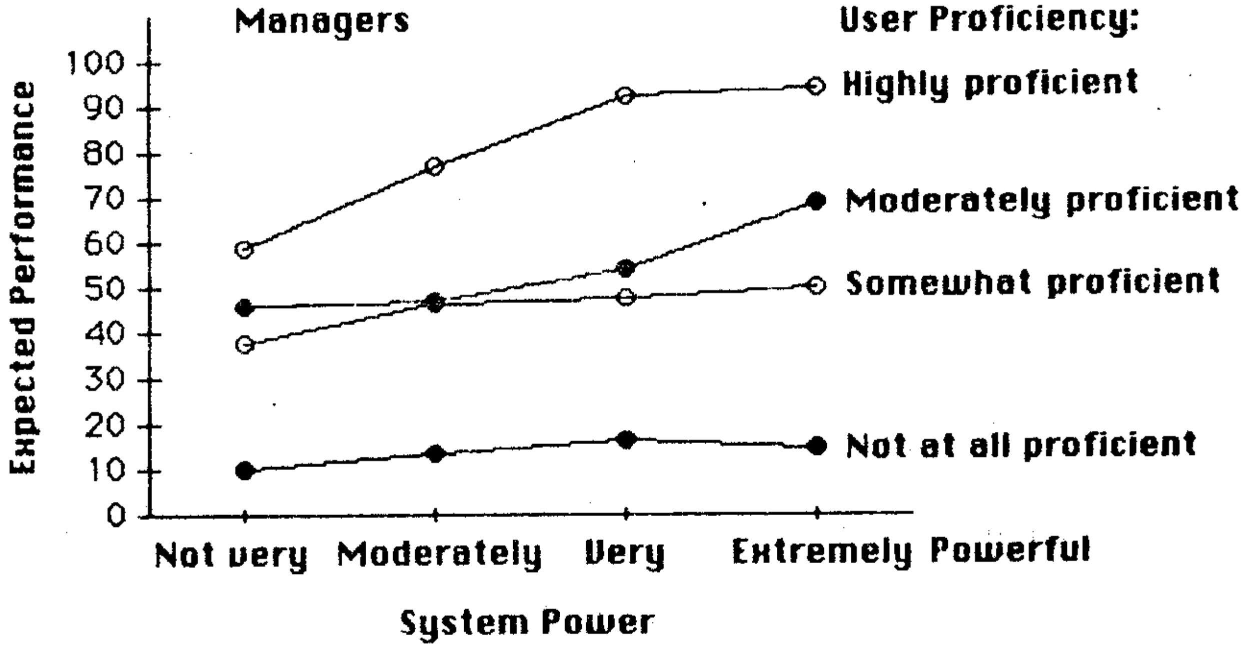
Figure Captions

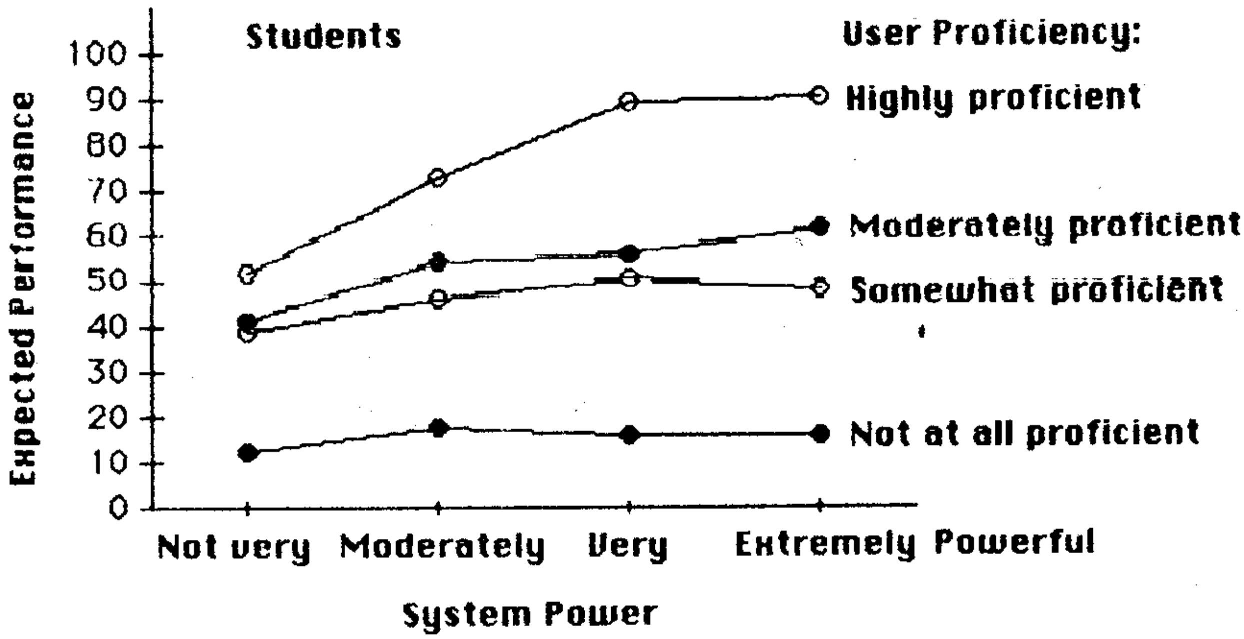
Figure 1. Patterns of expected performance as a function of levels of system power and user proficiency for the matching model, the averaging model, the multiplying model, the human/computer ratio model, and the computer/human ratio model.

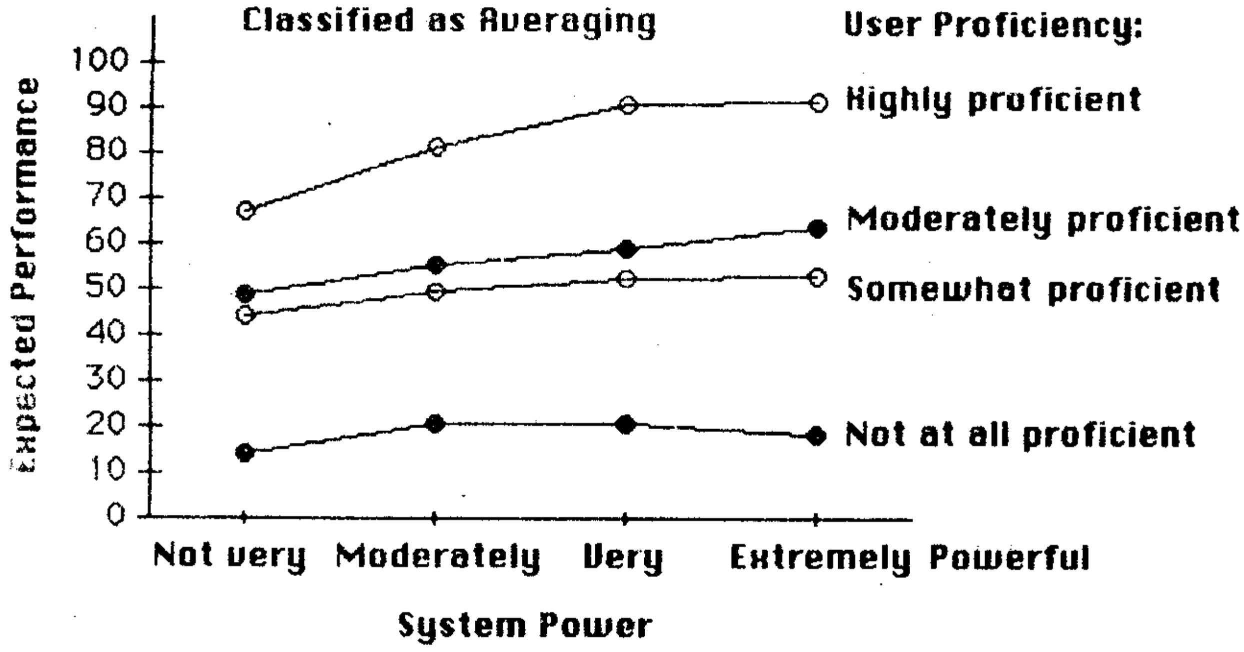
Figure 2. Mean ratings of expected performance as a function of system power and user proficiency for managers (n = 18) and students of management (n = 33).

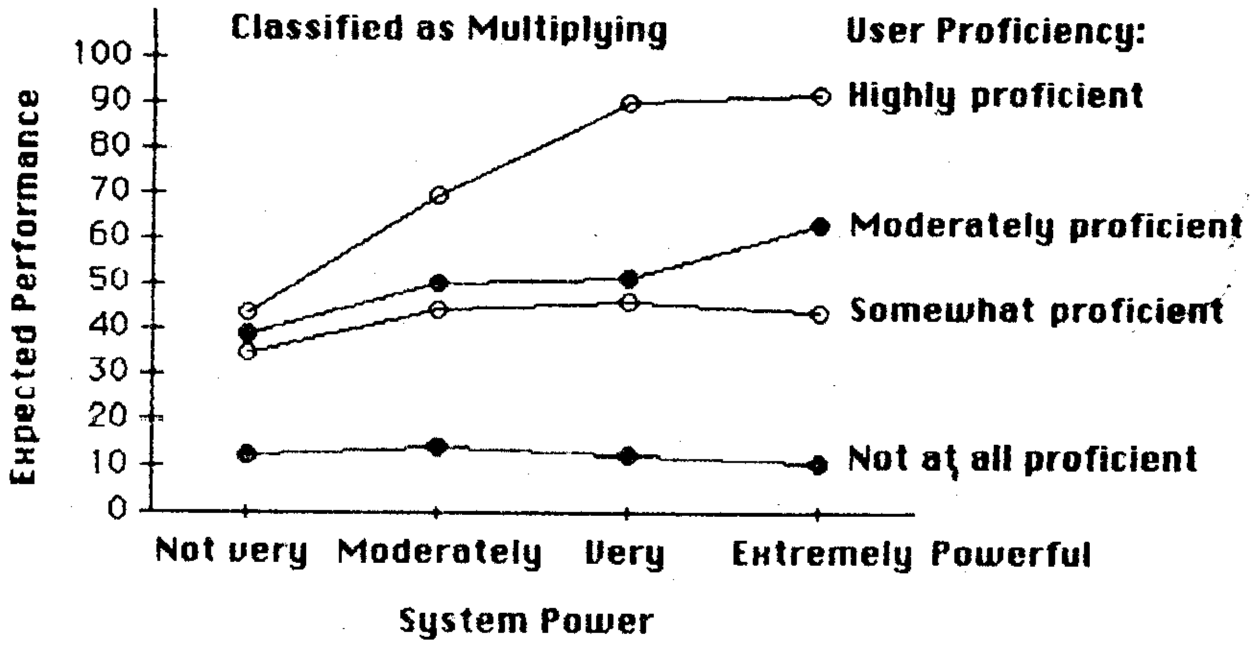
Figure 3. Mean ratings of expected performance as a function of system power and user proficiency for individuals classified by the averaging model (n = 13) and the multiplying model (n = 26).


Matching Model
Expected Performance
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
System Power
4
3
2
1
Averaging Model
Multiplying Model
Human/Computer Ratio
Computer/Human Ratio


Managers
User Proficiency:
Highly proficient
Moderately proficient
Somewhat proficient
Not at all proficient
Expected Performance
0
10
20
30
40
50
60
70
80
90
100
Not very
Moderately
Very
Extremely
Powerful
System Power


Students
User Proficiency:
Highly proficient
Moderately proficient
Somewhat proficient
Not at all proficient
Expected Performance
0
10
20
30
40
50
60
70
80
90
100
Not very
Moderately
Very
Extremely
Powerful
System Power


Classified as Averaging
User Proficiency:
Highly proficient
Moderately proficient
Somewhat proficient
Not at all proficient
Expected Performance
100
90
80
70
60
50
40
30
20
10
0
Not very
Moderately
Very
Extremely
Powerful
System Power


Classified as Multiplying
User Proficiency:
Highly proficient
Moderately proficient
Somewhat proficient
Not at all proficient
Expected Performance
100
90
80
70
60
50
40
30
20
10
0
Not very
Moderately
Very
Extremely
Powerful
System Power