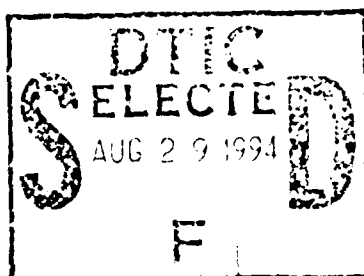
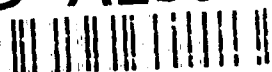




**Independent
Research
(IR)
and
Independent
Exploratory
Development
(IED)**

AD-A283 899



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**FY93
Annual Report**



94-27580



What you should know about the Navy Personnel Research and Development Center (NPRDC) . . .

We are an applied research center, dedicated to research and development in manpower, personnel, and training. Our aim is to improve the performance of individuals, teams, and organizations. The scientists on our staff represent a variety of scientific disciplines in the behavioral and cognitive sciences, economics, applied mathematics, and statistics. Our products are used by both military and civilian organizations.

. . . our strengths are:

Minimal Start-up Times

- We know the Navy and how to use scientific knowledge and new technologies to solve military problems.
- We have an experienced staff with long-term corporate memory and a "can do" attitude.
- We are located near key centers of military activities.

Solutions and Options Suited to Your Needs

- We have programs that extend across a spectrum of research, from basic scientific discovery through applied systems prototyping. We have the flexibility to explore options suited to your problems.
- We have a multi-disciplinary staff to address issues and solutions from several perspectives.

Strong Working Relationships

- We consider you our first priority and recognize that effective research, whether aimed at product development or problem solution requires that we work together as a team.

Access to Resources

- We are able to tap into resources at universities, other government agencies, and civilian contractors.
- We are dedicated to research and exploring technological options that apply to real-world problems.

Reasonable Costs

- We tailor our expertise to meet your needs. We can save you time and money by ensuring that you have the right people assigned to address your needs.

Current R&D Programs:

- **Workforce Management**—develops large-scale systems to improve the management of personnel resources, including suites of integrated, computer-based models, databases, and systems.
- **Personnel Testing**—improves personnel testing, including recruit selection and job classification testing, and performance measurement.
- **Person/Job Assignments**—increases the detailer's ability to make informed and accurate decisions when assigning sailors to new jobs and enable each detailer to service a larger constituency.
- **Classroom and Afloat Training**—incorporates advanced instructional and computer-based training technologies to create new and better ways to teach complex warfighting skills.
- **Organizational Productivity**—addresses productivity of individuals, combat forces, and organizations.

For more information, contact Mr. Ed Thomas, Public Affairs Officer, (619) 553-7814.

**Independent Research (IR) and Independent
Exploratory Development (IED) Programs:
FY93 Annual Report**

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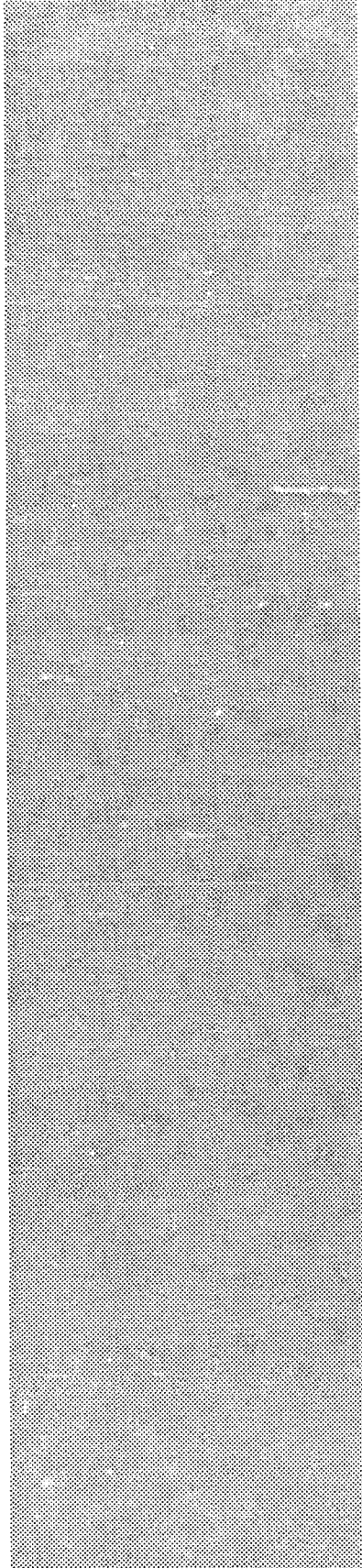
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**Navy Personnel Research and Development Center
San Diego, CA 92152-7250**

Contents

Introduction	1
Independent Research Best Paper	7
Nomination Rationale	9
The Effects of Workload on Performance and Feedback in a Simulated Work Environment	13
Independent Exploratory Development Best Project	27
Nomination Rationale	29
Optimal Enlisted Training Readiness Model	31
Independent Research Projects	39
Independent Exploratory Development Projects	47
Transitions	55
Publications and Presentations	59
Distribution List	65

Accession For	
NTIS	☒
CRA&I	☐
DTIC	☐
TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
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Introduction

This report documents the activities and accomplishments of the Independent Laboratory Research (IR, PE 0601152N) and Independent Exploratory Development (IED, PE 0602936N) programs at the Navy Personnel Research and Development Center (NPRDC) for FY93.

Scientists and engineers at NPRDC are encouraged by the Technical Director to generate new and innovative proposals to promote scientific and technological growth in the organization and the discovery of knowledge. Support for this is provided by discretionary funding furnished by the IR and IED programs of the Office of Naval Research. These programs support initial research and development of interest to the Navy with emphasis on the NPRDC mission areas of workforce management, and the acquisition, assignment, training, and effective utilization of personnel.

Funds are provided to the technical directors of Navy Laboratories to support innovative and promising research and development outside the procedures required under normal funding authorization. The funds are to encourage creative efforts important to mission accomplishment. They enable promising researchers to spend a portion of their time investigating basic scientific issues or pioneering new technology of relevance to the Navy. They can provide an important and rapid test of ideas that can help fill gaps in the research and development program. This may involve preliminary work on issues too risky to be funded from existing programs.

The funds also serve as means to maintain and increase the necessary technology base skill levels and build in-house expertise in areas likely to become important in the future. These programs contribute to the scientific base for future improvements in the manpower, personnel, and training system technology and provide coupling to university and industrial research communities.

The FY93 IR/IED programs began with a call for proposals in June 1992. Technical reviews were provided by supervisors and scientific consultants and six IR and four IED projects were funded. This report documents the results and accomplishments of these projects. Dr. William E. Montague administers the IR and IED programs, coordinating project selection, reporting, and reviewing to assure an innovative and productive program of science and technology.

For more information, contact Dr. William E. Montague
(619) 553-7849.

Tables 1 and 2 list the FY93/94 projects. Two papers (one IR and one IED) chosen by the Technical Director as "Best Papers of 1993" are presented. Subsequent pages contain brief reports of research progress during FY93.

Table 1

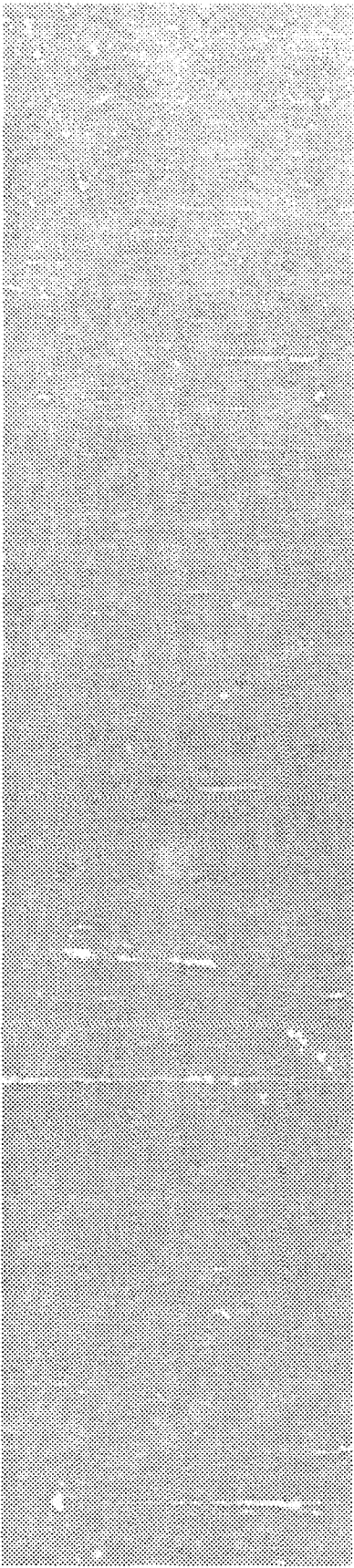
**Independent Laboratory Research
Work Units for Fiscal Years 1993 and 1994
(PE 0601152N)**

Work Unit	Title	Principal Investigator	Internal Code	Telephone (619) 55 or DSN 55	Fiscal Year Funding (K)	
					93	94
0601152N.R0001.01 ^a	Brain activity and performance: Advanced signal analysis using the wavelet	Trejo	13	37708	40.0	37.3
0601152N.R0001.05	Responses on computer surveys	Rosenfeld	01E	37658	45.0	0.0
0601152N.R0001.12	Individual differences in information acquisition and processing style	Morrison	12	39256	55.0	31.0
0601152N.R0001.14 ^a	Long-term retention of information and skills learned in school	Ellis	13	39273	30.0	31.1
0601152N.R0001.15	Optimization algorithms to solve class scheduling problems	Krass Sorensen	11	37895 37656	50.0	0.0
0601152N.R0001.16	Transfer for training in graphical environments	Ryan-Jones	13	37710	0.0	37.7
0601152N.R0001.17	Productivity in a simulated work environment	Tatum	16	37955	44.0	30.0

^aAdditional matching funds obtained from the Office of Naval Research, Navy Laboratory Participation Program.

Table 2
Independent Exploratory Development
Work Units for Fiscal Year 1993
(PE 0602936N)

Work Unit	Title	Principal Investigator	Internal Code	Telephone (619) 55 or DSN 55	Fiscal Year Funding (K)
					93
0602936N.RV36I27.03	Enlisted requirements model	Krass Thompson	11	37895 37925	50.0
0602936N.RV36I27.08	Evaluation of alternative prediction models for dichotomous criteria	Sands Folchi	12	37750	90.0
0602936N.RV36I27.09	A goodness of fit (GOF) test of minority vs. majority exclusion rates	Folchi	12	37750	30.0
0602936N.RV36I27.13	Cognitive and motivational effects of employee involvement interventions	Sheposh	16	37947	25.0
0602936N.RV36I27.14	Models and measures of organizational behavior	Houston	16	37959	15.0



Independent Research Best Paper

Nomination Rationale

Research Merit

Workloads have increased, and no doubt will continue to increase, during the current downsizing of the Navy and other services. Excessive workload has been associated with a variety of negative job behaviors and affective states (e.g., absenteeism, turnover, alcohol consumption, poor job performance, dissatisfaction, depression, stress). Increased workload could have a devastating effect on both civilian and military personnel if it is not managed properly. Therefore, it is important to understand the empirical relationships between workload, performance, and affective states, and to develop the theoretical underpinnings of these relationships.

Although the conceptual framework in the field is poorly developed, some theoretical relationships have been proposed. For example, the affective experience of stress is hypothesized to mediate the relationship between workload and performance (Cox, 1978; Kahn & Byosiene, 1992). In other words, high workload leads to lower performance in part because of the concomitant elevation in stress levels. As another example, the empirically-established inverse relationship between workload and performance is theoretically linked to the use of performance feedback. High levels of workload (levels that increase the level of arousal) can depress performance by altering the effective use of performance feedback cues in some situations (Kahneman, 1973, pp. 37-42). Understanding both the empirical and conceptual linkages between workload, performance, stress, and feedback can serve as a foundation for improved workload management in the armed services.

Research Approach/Plan/Focus/Coordination

Studying the effects of workload in actual work settings presents a bewildering array of obstacles, and extreme caution must be used in drawing scientific conclusions from such field studies. An alternative to the field study is work simulation. In a simulated work environment, variables can be effectively controlled and manipulated, and work performance and reactions can be measured with precision. With a high level of

control and precision, cause and effect relationships can be established with confidence, and theories can be tested under appropriate conditions. Moreover, work simulations provide a degree of realism that is not found in laboratory studies and rivals the realism found in field investigations (Locke, 1985).

For these reasons, the present research adopted a work simulation approach to the study of the effects of workload on organizational behavior. Key entry operators were recruited by a temporary employment agency to work in a simulated office environment entering documents into a computerized database. Workload was manipulated by the instructions given to the workers, and other, extraneous variables were controlled to prevent confounding influences. Measures of work performance, reported stress, and feedback seeking behavior were accurately recorded by the computers and analyzed by standard statistical tests. From the data collected in the study, the researchers were able to establish definitive empirical relationships between workload and other variables, and to test hypotheses based on their theoretical understanding of the effects of workload.

Difficulty of Problem Addressed

In real organizations, leaders and managers do not have the luxury of manipulating one set of variables and observing their effects on a precisely measured set of behaviors or emotional reactions. Every situation presents a unique set of circumstances, and the leaders/managers must rely on their past experience, or the advice of others, in their attempts to create effective and efficient organizations. Unfortunately, the experience and advice these decision makers receive is not based on well informed theory or well established empirical data. When the information is founded in good theory and sound empirical data, it is often very limited in its range of generality and application. The difficulty of the problem lies in the complexity of the situations and variables involved. This complexity makes it difficult to formulate comprehensive theories and to identify all relevant variables. The present study makes a significant contribution to our theoretical understanding of the effects of workload, but much remains to be done in theory development. Even greater challenges exist in the identification of important variables and their interrelationships.

Originality of Approach

Studies of organizational behavior generally fall into two categories (field research and laboratory research). Results garnered from field research are difficult to interpret, and results collected from laboratory research are difficult to generalize. The work simulation represents the best compromise between these two research strategies by allowing a high degree of control without sacrificing realism. The field of organizational science has not seen much research using work simulations despite its many advantages (Locke, 1985). To our knowledge, the present study is the only investigation of the effects of workload on performance and stress performed in a simulated work setting.

Potential Impact on Navy/Center Needs

The Department of the Navy (DON) clearly wants its operational units to perform at peak efficiency and be in the highest state of readiness. In the future, these goals must be achieved with fewer resources, and diminishing resources means the potential for higher workloads. Understanding the effects of higher workload on performance and stress, and modeling these relationships, can help future DON leaders predict and control outcomes and create the best possible fighting force for the 21st century. The Center has been on the leading edge of research in this area, and has one of the few research and development (R&D) labs in the nation that conducts work simulations. This research has application not only to DON's operational forces, but also to naval shore-based industrial and service organizations, other public agencies, and the private sector.

Potential of Achieving Impact on Naval Needs

In the 1980s, there were several unfortunate incidents in which naval operations had disastrous outcomes (e.g., USS STARK, USS VINCENNES, USS IOWA). In the case of the USS VINCENNES, one official report blamed the downing of a civilian Iranian airliner on "psychological stress" ("Downing of jet," 1988). The present study demonstrated that workload contributed to stress, and that stress then led to diminished performance. If these effects can be shown in a relatively "peaceful" work simulation, imagine how powerful they are

during operational exercises of naval forces. Controlled, scientific studies on the complex relationships between workload, performance, stress, and other psychological factors can have a large impact on the DON's need to prepare for its mission in the second half of this decade and beyond.

References

- Cox, T. (1978). *Stress*. Baltimore: University Park Press.
- Downing of jet said crew error. (1988, August 3). *The San Diego Union*, pp. A1, A12.
- Kahn, R. L., & Byosiore, P. (1992). Stress in organizations. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of industrial and organizational psychology* (pp. 572-650). Palo Alto, CA: Consulting Psychologists Press, Inc.
- Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.
- Locke, E. A. (1985). *Generalizing from laboratory to field settings: Research findings from industrial-organizational psychology, organizational behavior, and human resource management*. Lexington, MA: Lexington Books.

The Effects of Workload on Performance and Feedback in a Simulated Work Environment

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Dale N. Glaser
Delbert M. Nebeker*

Abstract

This study explored the relationships between workload, performance, stress, and feedback. Thirty-seven temporary employees worked in two-week shifts in a simulated work environment entering documents into a computer data base. The workers were divided into four groups representing two levels of qualitative workload and two levels of quantitative workload. Measures of ability, performance, stress, and the use of performance feedback were recorded. The results showed a direct relationship between workload and stress, an indirect relationship (stress was a mediating variable) between workload and performance, and an unexpected positive relationship between workload and feedback use. The study is among the few that provide a scientifically controlled demonstration of increased stress as a function of workload. More important, the study showed, under controlled conditions, that the decline in performance as a function of workload was mediated by the increased stress of the workers. Increases in qualitative workload were associated with increases in the use of performance feedback, a finding that was not expected given current theories of the relationship between arousal and the use of performance cues. Practical implications of the research are discussed.

Introduction

Increasing demands are being made on workers and managers alike to do more with less. Workloads have increased during the recent downsizing in the Navy and other services. This increase in workload could have a devastating effect on both civilian and military personnel if it is not managed properly. Excessive workload has been associated with a variety of negative job behaviors and affective states (e.g., absenteeism, turnover, alcohol consumption, poor job performance, dissatisfaction, depression, stress). Most of these studies are non-experimental in nature and, consequently, cause and effect relationships cannot be inferred with any degree of confidence (Kahn &

Byosiére, 1992, p. 601). Sales (1970) and Shaw and Weekley (1985) have provided some experimental evidence that workload is causally related to job performance and stress, but there is clearly a dearth of controlled studies in the field. Moreover, the links between empirical data and theory are not well developed. The present study aims to fill these empirical and theoretical voids by investigating workload, performance, and stress in a controlled work environment, and testing several hypotheses derived from organizational behavior theory.

Although the conceptual framework in the field is poorly developed, some theoretical relationships have been proposed. As noted above, when workloads exceed a critical level, increased workload is hypothesized to be directly related to stress (high workload leads to elevated stress) and inversely related to performance (high workload leads to lower performance). In addition, stress is hypothesized to mediate the relationship between workload and performance (Cox, 1978, Kahn & Byosiére, 1992). In other words, high workload leads to lower performance in part because of the concomitant elevation in stress levels.

The inverse relationship between workload and performance is theoretically linked to the use of performance feedback. High levels of workload (levels that increase the level of arousal) can depress performance by altering the effective use of performance feedback cues (Kahneman, 1973, pp. 37-42). This relationship between workload and feedback, however, is complicated by several factors. First, the relationship between arousal and performance is not linear. The well-known Yerkes-Dodson law (Yerkes & Dodson, 1908) states that performance is an inverted U-shaped function of arousal. Thus, at low levels of overall arousal, increased arousal can lead to increased performance, but at high levels of overall arousal, further increases in arousal can lead to decreased performance. Assuming that workload-induced arousal (stress) is sufficiently high, there should be both a decrease in performance and a reduction in the use of performance feedback consistent with the findings of Easterbrook (1959). A second complication is that the Yerkes Dodson law breaks down for simple tasks. For simple tasks, it takes exceedingly high levels of arousal to produce a decline in performance. Therefore, with simple tasks, even under very high levels of workload-induced stress, we might not observe a reduction in the use of performance feedback. Given this above description of the empirical and theoretical literature, and the various caveats, the following hypotheses were tested:

- Hypothesis 1:** There will be a direct relationship between workload and stress.
- Hypothesis 2:** There will be an inverse relationship between workload and job performance.
- Hypothesis 3:** Stress will mediate the workload/performance relationship (i.e., workload leads to reduced performance in part because of increases in concomitant stress).
- Hypothesis 4:** High workload will be associated with reduced use of performance feedback.

Method

Overview of Design

Thirty-seven employees were hired to work on a data-entry task in a simulated work environment similar to that described by Nebeker and Tatum (1993). The employees worked ten days (Monday through Friday for two weeks) in four-hour shifts. The task involved entering information from scientific references into a computerized data base. On the first day the employees were trained and allowed to practice the task. On the second day, the workers were divided into four experimental groups that represented four combinations of qualitative and quantitative workload. The workers were provided with computerized performance feedback on demand, and the computer recorded the frequency and duration of their feedback requests. Daily performance measures were also recorded by the computer. Each employee was administered a computerized survey each day that obtained self-reports of stress levels and feedback use.

Subjects

Forty subjects were initially recruited through a local employment agency. Three subjects failed to complete the study leaving 37 subjects included in the final analyses. The ages of the employees ranged from 19 to 52 with an average age of 28.51. There were eight males and 29 females in the study. Caucasians comprised 54.1% of the sample, 21.6% were Black, 10.8% were Hispanic, and 2.7% were Asian. Education level ranged from high school graduate to postgraduate.

Procedure

The employees job assignment was defined as a data entry operator in which they were to enter and maintain a computerized data base of literature citations. The subjects were paid at an hourly rate of \$7.25. Criteria for inclusion in the study were capability of typing at 35 words per minute and familiarity with computer keyboards. The temporary agency was responsible for supplying subjects that met these criteria. The applicants were informed that this work assignment was of a temporary nature and that there would be a research component to their employment, but in all other respects this was a typical job.

Workers were assigned to one of four groups. Each group represented one of four combinations of the levels within a 2 X 2 factorial design. The two factors were qualitative workload (single versus multiple task requirements) and quantitative workload (light versus heavy work demands). Group assignment to the different workload conditions was as follows:

Qualitative Workload. One group of workers was required to reach three simultaneous requirements (a high workload condition in which the workers tried to meet standards set for keystroke rate, accuracy, and time-use efficiency). A second group was required to pursue only a single task requirement (meeting a single standard that consisted of a composite of keystrokes, accuracy, and time use). The composite score was calculated by multiplying keystrokes per hour by (a) the accuracy rate and (b) the proportion of time spent in actual production. Hence, the composite score was a measure of correct keystrokes per productive hour.

Quantitative Workload. Half of the workers in each of the two qualitative workload groups was randomly assigned either a large quantity of work to accomplish (high workload) or a small quantity of work (low workload). The specific levels of work demanded of the two groups were determined by a pilot study.

Each employee within a group was scheduled to participate for a total of 40 hours (4 hours per day, 5 days per week, for two weeks). The first day of the study was devoted to training on the task, practice sessions, instructions on task requirements, and lessons on how to obtain feedback reports. Each group was told that from the second day until the final day (day 10) of the work assignment they should try to meet the task requirements, and that they would receive computerized feedback reports

indicating their progress toward these requirements. The workers were given unlimited access to on-line feedback reports so they could monitor their own progress toward the task requirements. These reports provided information on all relevant dimensions of performance (i.e., the workers received reports on their keystroke rate, the accuracy of the data they entered, how efficiently they used their time, and a composite measure of these three). At the end of each day, the workers completed a survey that asked many work-related questions. Two critical sets of questions assessed their stress level and the use of feedback reports.

Measures

Performance. There were three separate measures of performance: (a) keystrokes per hour, (b) proportion of keystrokes accurately entered, and (c) proportion of time spent actually entering data (i.e., time on task excluding breaks, looking at reports, answering survey questions, etc.). The computers were programmed to collect this information and feed it back to the subjects and the researchers. The measure used for comparing performance of the different groups was the product of keystroke rate, accuracy, and time efficiency for days 2 through 9 (day 1 and 10 were excluded because very little production occurred on those days).

Feedback Use. Computer software monitored which reports the workers used, how often they selected a given report, and how much time they spent viewing each report. This objective information was then combined to form a measure of time spent per report (i.e., the total time spent viewing reports divided by the total number of reports selected) for days 2 through 9. An additional measure of feedback use was obtained from survey data that asked the subjects to estimate (on a 5-point rating scale) the extent to which they used each of the several feedback reports available to them. The average rating for all reports for days 2 through 9 was used as another dependent measure of feedback use.

Stress. Stress level was measured by survey items that formed a rating scale similar to that used by Morris, Davis, and Hutchings (1981). The items asked the workers to rate (on a 5-point scale) the extent to which they both worry and show symptoms of emotionality during the job. Typically, worry and emotionality form separate scales, but we combined the two scales into a single "stress" scale (average Cronbach Alpha over the nine days was .83).

Ability. On two separate days (day 1 and day 4), the subjects were administered work sample tests. These tests consisted of ten standard documents, and the subjects were instructed to enter the data from the documents into the computer as quickly as possible while minimizing errors. The second work sample tests was used as a measure of ability and served as a covariate in the analysis of the first three hypotheses.

Results

The results of the study confirmed the first three of the four hypotheses. In the analyses of the first three hypotheses, quantitative workload (amount of work) and qualitative workload (number of different requirements) had comparable effects on performance and stress, and there were no interactions between the two workload manipulations on either criterion variable. These separate workload variables were combined into a single workload variable. The single workload variable had three levels (low, moderate, and high). The lowest level was composed of the light demand/single requirement group. The highest level was composed of the heavy demand/multiple requirement group. The moderate workload level combined the remaining two groups.

Using this new workload variable, support for Hypotheses 1 (a direct relationship between workload and stress) is shown in Figure 1. Figure 1 shows that the lowest level of stress occurred in the low workload condition, the highest level of stress occurred in the high workload condition, and an intermediate degree of stress was reported in the moderate workload condition.

Figure 1 also provides data consistent with Hypotheses 2 (an inverse relationship between workload and performance). Figure 1 shows that as workload increased from low to high, performance decreased from approximately 5800 to 5000 correct keystrokes per productive hour. The figure shows performance expressed as correct keystrokes per productive hour (i.e., only the correct keystrokes were calculated, and these keystrokes were adjusted by the proportion of each hour the subject spent actually entering data). This measure of performance reflects the achievement of both single and multiple requirement groups because in both cases the subjects were evaluated on raw keystrokes, accuracy, and time efficiency. The multiple requirement group was required to meet separate

requirements for keystrokes, accuracy, and time efficiency, whereas the single requirement group was supposed to achieve a single level of performance based on a composite of keystrokes, accuracy, and time efficiency.

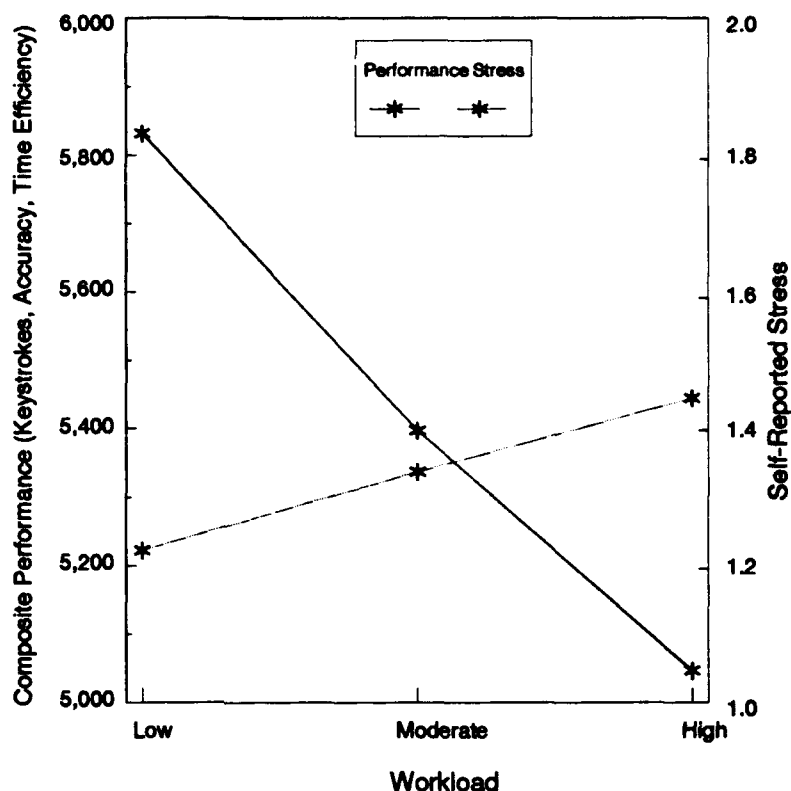
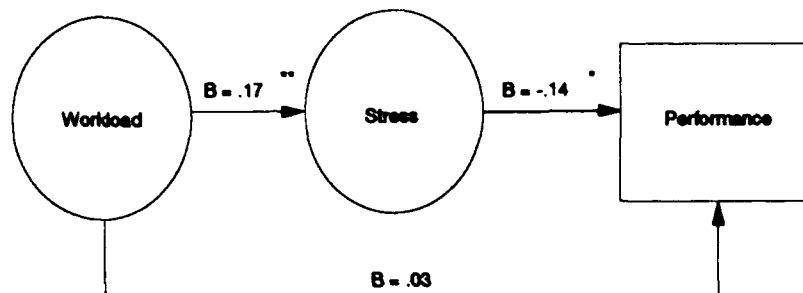


Figure 1. The Effect of Workload on Performance and Stress

Hypothesis 3 stated that stress would mediate the relationship between workload and performance.

Figure 2 shows the path analysis with stress as a mediating variable between workload and performance. Consistent with Hypothesis 3, Figure 2 shows that the two path coefficient between (a) workload and stress and (b) stress and performance are significant. For the purposes of the path analysis, subjects/day combinations were used as the unit of observation, and ability was used as a covariate to partial out the within- subjects variance. The path analysis was performed according to procedures outlined by Pedhazur (1982, pp. 580-593). The significant path coefficients indicate that the relationship between workload and performance shown in Figure 1 is mediated by workload-induced stress. In other words, there is no significant direct path from workload to performance; the relationship between workload and performance is completely mediated by stress.



B = Standardized Regression/Path Coefficient

* $p < .05$

** $p < .001$

Figure 2. Path Analysis of Effect of Workload on Performance as Mediated by Stress

The last hypothesis (Hypothesis 4), which stated that the use of performance feedback would decline as workload increased, did not receive any support. The top panel of Figure 3 shows the amount of time spent viewing each feedback report by workers in each of the four workload conditions. The bottom panel of Figure 3 shows the rated usage of the reports in each of the four workload conditions. Figure 3 suggests that the relationship between workload and feedback is complex. With respect to the duration of report viewing, a regression analysis was performed with duration (time spent viewing each report) as the criterion variable and number of requirements (single versus multiple) and amount of work (light versus heavy) as the predictor variables. (Ability was not used as a covariate in this and the following analysis because it was not correlated with the criterion variables). The analysis revealed that, contrary to expectation, workers with multiple requirements (high workload) spent significantly more time viewing their feedback reports than workers with a single requirement (low workload), $F(1, 34) = 5.03, p < .05$. The analysis also failed to show any main effect for amount of work (light versus heavy) or any interaction between the two factors ($p > .05$). With respect to the workers' reported usage of the reports, regression analysis again failed to support the hypothesis. As suggested in the bottom panel of Figure 3, there was a significant interaction between amount of work and number of work requirements, $F \text{ change}(3, 32) = 5.70, p < .05$, but no main effects for either of the two predictor variables ($p > .05$). Close inspection of the bottom panel of Figure 3 reveals that, for the group given heavy work demands, the workers assigned a single requirement reported

using the reports less often than the workers assigned multiple requirements. This finding is consistent with the results for report viewing duration. For the group given light work demands, however, the reverse pattern emerged; workers assigned a single requirement reported using the feedback less often than workers assigned multiple requirements. In general, evidence for decreased use of feedback with increased workload did not appear in this study.

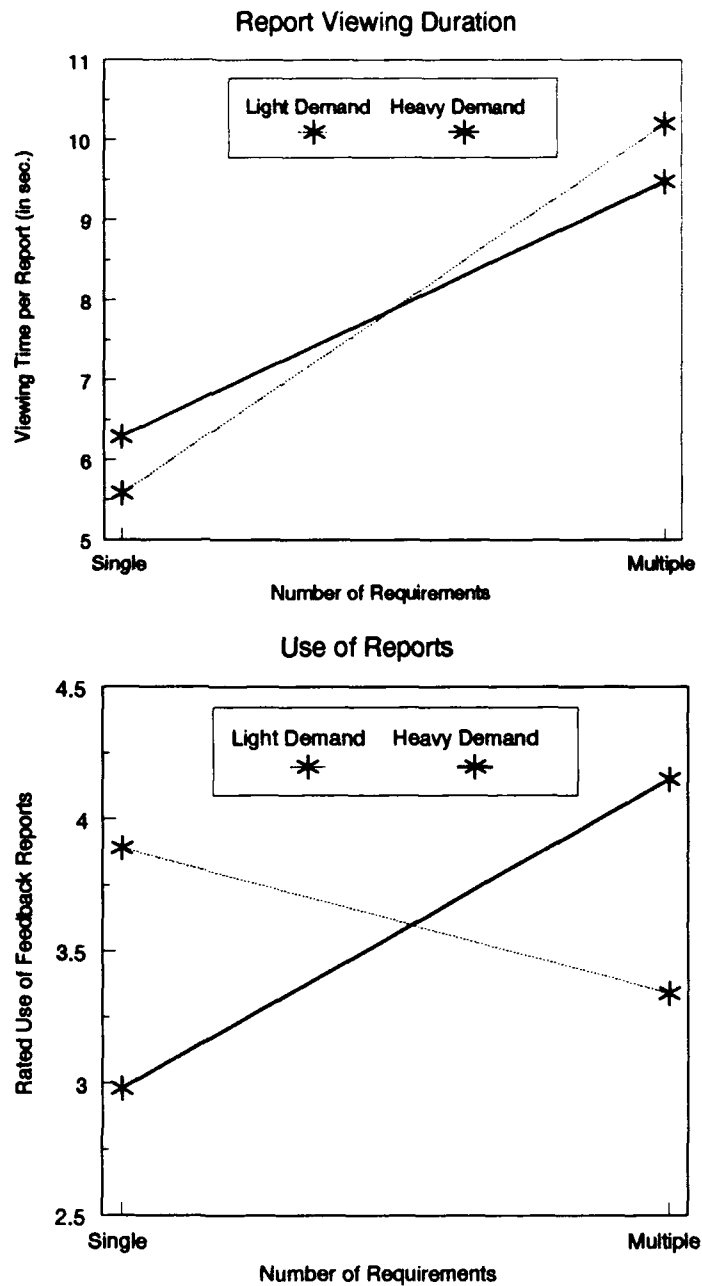


Figure 3. Report viewing and usage as a function of number of requirements (single vs. multiple) and amount of work (light demand vs. heavy demand).

Discussion

The present study investigated the effects of workload on stress, job performance, performance, and feedback from an empirical and theoretical perspective. Empirically, the study demonstrated that, under controlled conditions, workload increases stress and (indirectly) lowers performance. These cause and effect relationships between workload and stress and workload and performance have often been asserted, but rarely demonstrated under scientifically controlled conditions.

From a theoretical perspective, the study seems to have demonstrates the link between arousal and performance expressed by the Yerkes-Dodson law. Given a sufficiently demanding task, the Yerkes-Dodson law states that increased arousal leads to degraded performance. Our results showed that stress mediated the relationship between workload and performance, and this strongly suggests that workload has its primary influence on performance because it increases the level of general arousal.

The hypothesis that the use of performance feedback would diminish as workload increased was not supported by this study. The data indicated that workers assigned multiple requirements spent more time looking at feedback reports than workers assigned a single requirement. This finding, although contrary to the hypothesis, seems reasonable at first glance. After all, if workers are asked to achieve several things at one time, it only makes sense that they would look at more feedback reports. We specifically did not analyze the frequency of selecting reports because we expected this result. What we did analyze was the amount of time the workers spent viewing each report they selected. Our findings showed that the workers with multiple requirements spent more time viewing the reports they selected than the workers with a single requirement. Moreover, some of the workers pursuing multiple requirements (those assigned a heavy work demand) also reported using the feedback reports to a greater extent than their single requirement counterparts. Both of these findings are contrary to Hypothesis 4.

Theoretically, we would expect that if imposing multiple requirements increases the qualitative workload, the workers should reduce the amount of time they spent per report and

decrease the overall use of reports. This theoretical expectation is derived from the work of Easterbrook (1959) who showed that increased arousal leads to a reduction in the use of performance cues. The fact that we did not find a decrease use of performance feedback may be related to at least two factors. First, it may be that the overall level of stress (arousal) was not high enough to yield the expected decrease in feedback use. Indeed, examination of Figure 1 reveals that the overall stress levels were quite low (less than two units on a 5-point scale). Interestingly, the changes in stress levels resulting from increased workload were sufficient to affect performance, but apparently not high enough to lower the use of feedback cues.

The second factor that might account for our failure to witness any reduction in the use of feedback under high workload conditions was task complexity. Recall that the Yerkes-Dodson law maintains that for complex tasks, elevated stress may lead to reduced performance. Apparently the key-entry task used in this research was sufficiently complex to show the stress/performance relationship predicted by the Yerkes-Dodson law (see the significant path coefficient between stress and performance in Figure 2). Nevertheless, the task may not have been complex or demanding enough to discourage the use of performance feedback. The key-entry task used here is primarily a psychomotor task and is not very mentally demanding or cognitively complex. Because the selection and use of feedback information is a cognitive task, perhaps decrements in the use of feedback occur only in mentally demanding tasks and not in psychomotor tasks such as this. Further research is required to explore this possibility.

Conclusions

Navy and other DoD organizations are entering into a period of great uncertainty. Increasing demands will be placed on these organizations to perform at the same or higher levels with dwindling resources. If these demands are not managed well, increased stress and lower performance can be expected. It is clear from the present experiment that workload does increase stress, and that this increased stress is primarily responsible for lower work performance. The implication, then, is that management systems designed to lower stress will also improve performance. There are many tools and techniques that have been recommended for lowering stress and improving performance. Among these are management systems that encourage worker participation and employee involvement.

Research has shown that opportunities for worker participation is strongly associated with reductions in job stress (Margolis, Kroes & Quinn, 1974) and improved performance (Lawler & Mohrman, 1989). Total Quality Management (TQM) and Productivity Gain Sharing (PGS), which have been endorsed by the Navy and DoD, are likely to reduce stress and enhance performance in the workplace because they both emphasize worker participation, involvement, and empowerment. The success of these and other management systems, however, rest on a foundation of basic scientific knowledge in the areas of organizational behavior, work motivation, human cognition, and human emotions.

Recommendations

The research reported here advances our knowledge and understanding of the relationship between workload, stress, and performance. The findings with respect to the use of performance feedback, however, are puzzling. Further research is needed to discover the relationships between stress, performance, and the use of performance feedback. Controlled scientific studies are required to uncover the empirical relationships between levels of stress, degree of task complexity, and use of performance feedback. Theoretical developments should expand into an examination of the difference between psychomotor tasks and more cognitively demanding tasks. Studies, such as the present investigation, that address basic empirical and theoretical questions, form the foundation for improving organizational efficiency and effectiveness in the Navy, government, and the private sector.

References

- Cox, T. (1978). *Stress*. Baltimore: University Park Press.
- Easterbrook, J. A. (1959). The effects of emotion on cue utilization and the organization of behavior. *Psychological Review*, 66, 183-201.
- Kahn, R. L., & Byosiore, P. (1992). Stress in organizations. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of industrial and organizational psychology* (pp. 572-650). Palo Alto, CA: Consulting Psychologists Press, Inc.
- Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.

- Lawler, E. E., & Mohrman, S. A. (1989). High involvement management. *Organizational Dynamics*, April, 27-31.
- Margolis, B. L., Kroes, W. H., & Quinn, R. P. (1974). Job stress: An unlisted occupational hazard. *Journal of Occupational Medicine*, 16, 659-661.
- Morris, L. W., Davis, M. A., & Hutchings, C. H. (1981). Cognitive and emotional components of anxiety: Literature review and a revised worry-emotionality scale. *Journal of Educational Psychology*, 73(4), 541-555.
- Nebeker, D. M., & Tatum, B. C. (1993). The effects of computer monitoring, standards, and rewards on work performance, job satisfaction, and stress. *The Journal of Applied Social Psychology*, 23, 508-536.
- Pedhazur, E. J. (1982). *Multiple regression in behavioral research*. Holt, Rinehart, and Winston: New York.
- Sales, S. M. (1970). Some effects of role overload and role underload. *Organizational behavior and human performance*, 5, 592-608.
- Shaw, J. B., & Weekley, J. A. (1985). The effects of objective work-load variations of psychological strain and post-work-load performance. *Journal of Management*, 11(1), 87-98.
- Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to the rapidity of habit-formation. *Journal of Comparative Neurology of Psychology*, 18, 459-482.

FY 93 Publications and Papers

- DeYoung, P. H. (1993, August). *The effects of group size and expected level of productivity gain sharing success on motivation, job performance and job satisfaction*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.
- Glaser, D. N. (1993, August). *The effects of complexity and amount of workload on strain and performance*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.

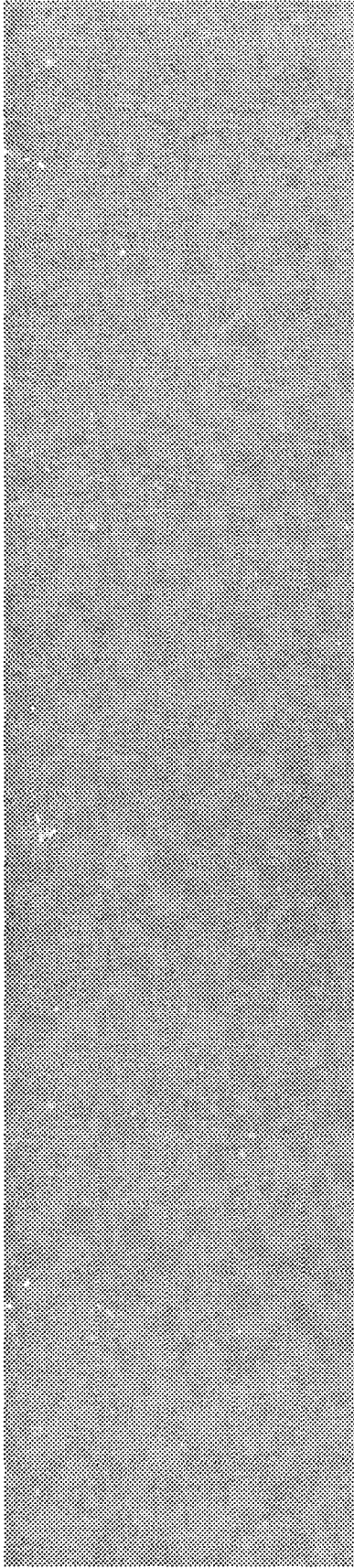
Nebeker, D. M., & Tatum, B. C. (1993). The effects of computer monitoring, standards, and rewards on work performance, job satisfaction, and stress. *The Journal of Applied Social Psychology*, 23, 508-536. (Work done in FY85/86).

Riemer, R. A. (1993, August). *The effects of productivity gain sharing and employee involvement on job performance*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.

Tatum, B. C. (1993, August). *The effects of fixed versus continuous improvement goals on productivity and affective reactions*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.

Tatum, B. C. & Nebeker, D. M. (1993, June). *The effects of fixed versus continuous improvement goals on productivity and affective reactions*. Paper presented at the Fifth Annual Convention of the American Psychological Society, Chicago, Illinois.

Tatum, B. C. & Nebeker, D. M. (in process). The effects of system control and feedback errors on job performance and affective reactions. *Academy of Management Journal*.



Independent Exploratory Development Best Project

Nomination Rationale

Originality/Technical Merit

The current draw-down in the Navy has reemphasized the need to relate training plans to fleet readiness. Navy training must justify training budgets and take school-house cuts in ways that do the smallest damage to the fleet. Both the Chief of Naval Education and Training (CNET) and the Bureau of Naval Personnel (BUPERS) have grappled with these problems, but with little success. An exploratory approach to the problem requires novel definitions of readiness and applications of Navy data. Theoretically the combinatorial problem to identify critical ratings requires new algorithms to get optimality.

Research Approach/Plan/Focus/Coordination

In previous IED and 6.3A projects, NPRDC approached this problem from two separate directions that were linked in the current project. This research developed a model that ties the Optimal Enlisted Requisition Model to the "C" School Planning System. The new model translates fleet readiness into "C" School requirements and includes budget constraints for the school system. The model was optimally solved with a fan approximation method that gets upper and lower bounds of an optimal solution. Successive runs of the model give a curve connecting fleet personnel readiness and training costs and specify the critical ratings at different levels of readiness and cost.

Difficulty of Problem Addressed

The principal difficulties in studying the effects of enlisted training on fleet readiness include defining readiness in a way that encompasses the fleet's needs and that specifies the critical skills with the greatest impact on readiness; linking the readiness measure to training plans at the Navy Enlisted Classification (NEC) code level; and building a model that accounts for the stochastic nature of rotation and flow from recruit input to basic skills training to advanced skills training. The problem is

complicated by the cross-utilization of skills, the reusability of skills on later tours, and by the difficulties of getting training cost and fleet readiness data.

Potential Impact on Navy/Center Needs

NPRDC built the "C" School Planning System whose prototype has been used for 5 years in BUPERS and 3 years at CNET. The system crudely plans new training requirements based on fleet demands, course utilization rates, and constraints on class capacities. However, the system does not measure the impact of training on readiness. Furthermore, NECs are planned one-at-a-time and critical NECs are never singled out. While the "C" School Planning System has significantly speeded up the process of making training plans and revising them based on changing fleet needs, the system is inhibited by the lack of a comprehensive model that calculates training plans from readiness. This IED research provides a first model and also the formulations and definitions for future work in readiness.

Productivity

The effort was very productive. Using the model the Navy can, for the first time relate the cost of skill training to mission readiness. In the past, the Navy was growing and had the resources it needed so planning could be inexact, but that has now changed. The model will play an important role in planning training requirements in the current atmosphere of constrained training resources. A research paper on the work will be given at a conference and has been submitted for publication in a journal.

Appropriateness of IED Support

IED support was provided to accomplish an important unfunded, novel technology goal. The historic lack of progress on relating training requirements and costs to fleet readiness shows the complexity of the problem. The difficulties involved have kept the problem from normal research funding. The mathematical model developed in this project is a major first step in showing the inter-relationship of training requirements, constraints and fleet readiness. Also, the mathematical algorithms developed for the project are still new and require further testing.

Optimal Enlisted Training-Readiness Model

Iosif A. Krass and Stephen Sorensen

Background Rationale

The Navy maintains over 800 combat units. Each combat unit must report its personnel readiness which is based in part on manning within its missions. Manning is defined as the percentage of manpower requirements filled by on-board personnel. Each mission has a readiness measure (M-rating). The readiness measure for the entire unit, the C-rating, is equal to the minimum M-rating among the missions within the unit. A mission for a unit requires personnel with different attributes to support operational capabilities. Personnel are characterized by skill (ratings or RCN—Rate Code). A shortage of essential personnel degrades a mission.

The Navy also develops a training plan for the 1,000 "C" Schools needed to maintain skills for its enlisted personnel. However, the current enlisted distribution planning process in the Navy cannot relate training plans to fleet readiness. In particular, Navy training must justify training budgets and, if necessary, take schoolhouse cuts in ways that do the smallest damage to fleet readiness.

Previously, the training-to-readiness problem was approached from two separate directions. The Optimal Enlisted Requisition Model was developed to determine requirements by skill-RCN and to provide a given level of fleet readiness, based on data on necessary manning for different missions (providing a given level of mission and unit readiness, i.e., demand of the fleet) and data on the expected fleet supply of personnel with different skills. The model belongs to a class of optimization problems known as networks *with* side constraints. The presence of network structure in mathematical programming models can greatly speed up the solution process through the use of specialized optimization techniques and data structures which have been developed over the past two decades. However, additional nonnetwork constraints complicate the task. Two approaches were developed to get a solution of the Optimal Enlisted Requisition Model. One approach, worked out at The Wharton School, University of Pennsylvania with the cooperation of Professor Zenios, is based on applying the Linear-Quadratic Penalty algorithm to the side constraints of the

model. Another approach, worked out at NPRDC, is based on using a special network (fan network) to approximate an optimal solution of balance type constraints for a unit's readiness requirements.

The first approach requires a stiffer constraint on the model and a super computer must be used to calculate an optimal solution. The second approach is more flexible in the sense of changes to the original model and because it requires only medium class computers like the IBM 4381/12 which is readily available. In this paper, we use the second approach to create a model and to calculate an optimal solution or series of optimal solutions.

The second direction for attacking the training-to-readiness problem consists of developing the NEC "C" School Planning System. The "C" School Planning System plans NEC training requirements based on fleet demands (using authorizations and inventory), course utilization rates, and constraints on class capacities. However, as was mentioned before, the NEC "C" School Planning System does not measure the impact of training on readiness. Furthermore, NECs are planned one-at-a-time and critical NECs are never singled out.

We developed a model to link these two systems, to translate fleet readiness requirements into "C" school requirements for different ratings, and to include budget requirements for whole school system as well as for different ratings.

Approach

We modeled a set of about 15,000 technical enlisted sailors assigned to the set U of about 800 combat units. Every unit $u \in U$ has its own composite $c \in C$, such as sea, shore, or submarine.

Every person is characterized by his/her technical background (rating) $r = 1, \dots, RC$ and experience (paygrade). In this model paygrade falls into two categories: $p = 2$ for junior people with paygrades E-1 through E-4, and $p = 1$ for senior people with paygrades E-5 through E-9. All enlisted sailors are divided into two groups: a roller who rotates to a new duty station and an avail who has just completed Navy technical "C" school. An avail can be assigned to any unit. A roller is assigned to a unit with a different eligible composite than his/her current unit (e.g., sea to shore). The average cost of education for an avail is defined by the rating r and is equal to s_r . The majority of rollers also should be reeducated, i. e., graduate a "C" school

corresponding to his/her rating, to remain current with the constantly changing fleet technology. In the current model we assume a reeducation rate for rollers of 90% which is accepted by Navy planners. To put this fact in the model we assume that every roller should go to "C" school, but the cost of his/her education for the rating r is equal $s_r^1 = 0.9 \times s_r$. If a mission requires a person with a rating r and there is none available to be assigned to that rating (no avails or rollers) we assume that a person can be reeducated from another rating to the rating r , but it will cost more: $s_r^1 + \delta$, where δ is fine for cross-rating reeducation. Currently, in the model we assume that $\delta = \$4,000$. This kind of cross rating assignment is, generally speaking, "unlawful," although happens in real life. We applied those assignments in our studies only in special cases described below. The cost of "C" school education varies considerably with ratings. In Table 1 we show an average cost of education per student for some important ratings.

Table 1

**Cost of Education Per a Student
for Some Important Ratings**

Ratings	Cost
Boatswain's Mate (BM)	6,643
Machinist's Mate (MM)	8,132
Electrician's Mate (EM)	8,455
Radioman (RM)	10,149
Aviation Electronics Technician (AT)	11,379
Operations Specialist (OS)	12,009
Electronics Technician (ET)	12,120
Explosive Ordinance Disposal Specialist (EOD)	14,529
Sonar Technician G (Surface) (STG)	25,613
Fire Control (FC)	40,489

A combat unit u should be able to fulfill certain missions $m \in \{1, \dots, 19\}$, which relate to defense, attack, survivability, or reconnaissance. To be able to fulfill those missions a unit u is authorized (scheduled) to have B_{um}^1 senior personnel for mission m and B_{um}^2 overall personnel. If $P B_{um}^1$ is the number of senior people currently on the unit u to fulfill mission m (are

countable for mission m) and $P B_{um}^2$ is total number of people countable for the same mission, then readiness, R_{um} , to fulfill mission m by the unit u is defined as

$$R_{um} = 10 - \frac{\min[(x_{um}^1 + 5), x_{um}^2, 100]}{10} \quad (1)$$

Here, $x_{um}^1 = \frac{PB_{um}^1}{B_{um}^1}$ is manning percentage of senior people in mission m on the unit u , and $x_{um}^2 = \frac{PB_{um}^2}{B_{um}^2}$ is percentage of overall (i. e., senior and junior people together) manning for this mission on this unit. The lesser value R_{um} corresponds to the more ready units u for the mission m . It is important to note that the same person, depending on his/her skill rating r , can be counted for multiple missions after assignment to the unit u . The above formula shows that the readiness calculation for the overall manning percentage is counted exactly, but 5% is automatically added to the manning percentage of senior personnel. That is, senior people are more important for making a unit operable for a mission, and they can do a job originally assigned to a junior person, if necessary.

Correspondingly, overall readiness of the unit u is equal to:

$$R_u = \max_{m \in M_u} R_{um} \quad (2)$$

where M_u is the set of all missions that unit u is required to perform. In other words, the readiness of unit u is defined by the worst ready mission, or by the worst manned mission. Likewise, the readiness R of the set of combat units U is defined by the worst ready unit $u \in U$; that is,

$$R = \max_{u \in U} R_u \quad (3)$$

The Navy personnel readiness problem consists of assigning the given set of people to combat units to increase overall readiness, or to make R as small as possible. The Enlisted Training-Readiness problem adds to the above problem the minimization of training costs. In the other words, the given readiness of the fleet should be reached by minimum possible training costs.

Results

Our study started with an example of demand and supply for the Navy Readiness problem. We calculated optimal solutions of the Training Readiness problem by varying the value of target readiness R which should be reached by the fleet, from $R = 10$ (zero manning of all missions) to $R = 0$ (corresponding to 100% manning of all missions on every unit). The different values of parameter R correspond to measurements of fleet readiness C value accepted in the U.S. Navy (Thompson, Krass, & Liang, 1991):

$R \leq 1$ —corresponding to $C = 1$ —fully combat ready;

$1 < R \leq 2$ —corresponding to $C = 2$ —substantially combat ready;

$2 < R \leq 3$ —corresponding to $C = 3$ —marginally combat ready;

$3 < R$ —corresponding to $C = 4$ —not combat ready.

In the example without cross rating substitution, described in an earlier section, the maximum readiness of the fleet which can be reached is $C = 3$ due to an insufficient supply of some special ratings (EOD, STG). To get final results we permit, as a last resort (penalize those moves considerably $\delta = \$4,000$, where δ is a penalty for cross rating moves), the optimizer to make cross rating assignments. As we already mentioned, those moves, being extremely undesirable, happened often in real life. It looks like these moves do not interfere too much with our study, because there was less than 1% cross rating assignments of total assignments with training cost less than 1% of total training costs for $C < 3$.

In the Figure 1, we present a total training cost in millions of dollars to reach different values of personnel readiness needed by fleet. The curve is rather steeply increasing and can be approximated by exponent: $1.9 \times 10^{0.0206 \cdot x}$, especially in the area $x > 70$ or $C \leq 3$. The exponential character of the curve can be explained by the fact that more missions need to be manned to reach complete readiness of the fleet. In particular, to reach the level of marginal readiness $C = 3$ the training system will cost about 24 million dollars, but to reach 100% manning of all

missions, the system should spend 208 million dollars (i.e., 10 times more) although, readiness increases only 30% (see Figure 1).

The total number of training students required by the fleet for different degrees of readiness behaves in approximately the same manner. The corresponding curve is presented in Figure 2. As with training cost, to reach readiness $C = 3$ about 2,400 sailors should get training, but to get all missions manned at 100%, about 19,000 sailors should get training—about nine times more.

The similarity of curves in Figure 1 and Figure 2 is due to the fact that the process of minimizing total training costs manages to keep an average training cost per student at about \$10,000, independently of the rating of trained students and the degree of fleet readiness. As Table 1 shows, training cost per student is considerably different depending on the rating of the trained person. The curve of average training cost depending on fleet readiness is shown in the Figure 3. As we can see, on nearly the whole range of fleet readiness (up to $C = 2$) the average training cost is less than \$10,000. Only at the end, when all missions must be totally ready, does the average training cost go up, because more expensive technical people must be trained.

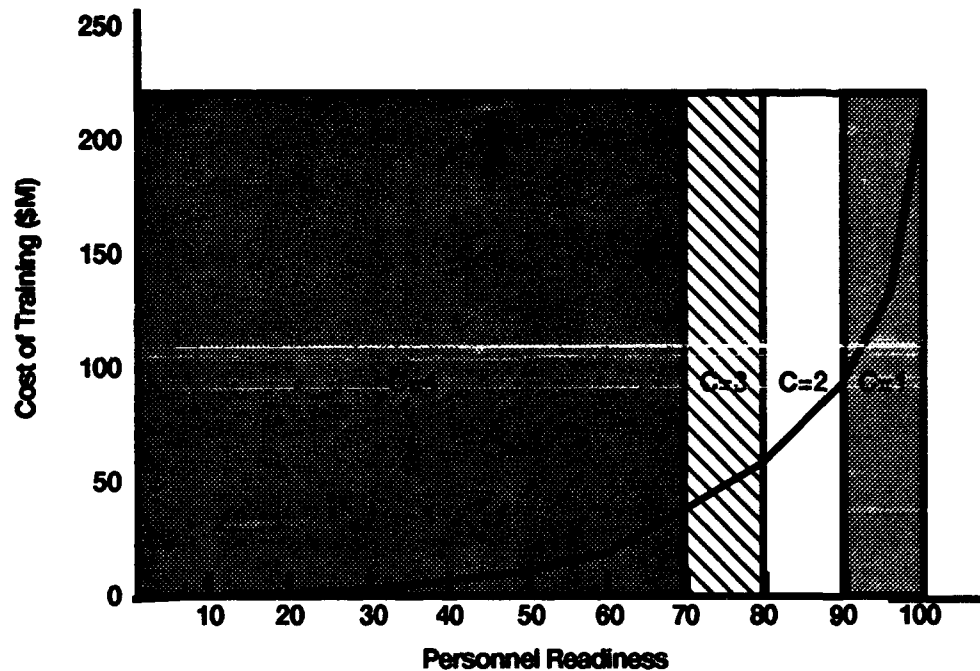


Figure 1. Total training cost in millions of dollars.

Total training cost per rating changes rather randomly up to system level of readiness $C = 3$, i.e., more than 70% of the worst missions manned. Then more money must be spent on the more technical ratings. In Table 2, we show the four most expensive ratings for different levels of fleet readiness.

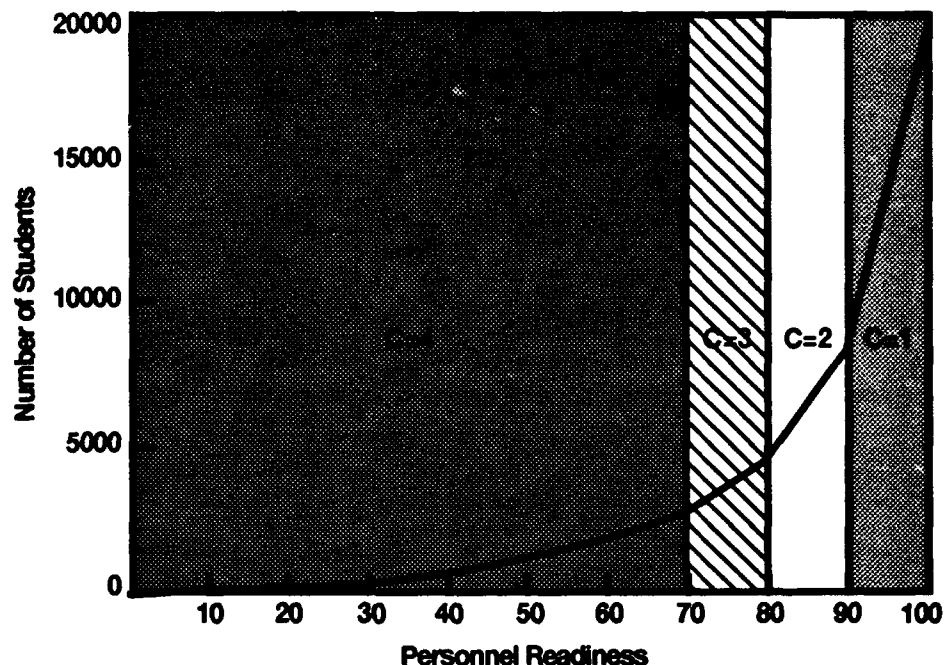


Figure 2. Total number of students to be trained for different levels of personnel readiness.

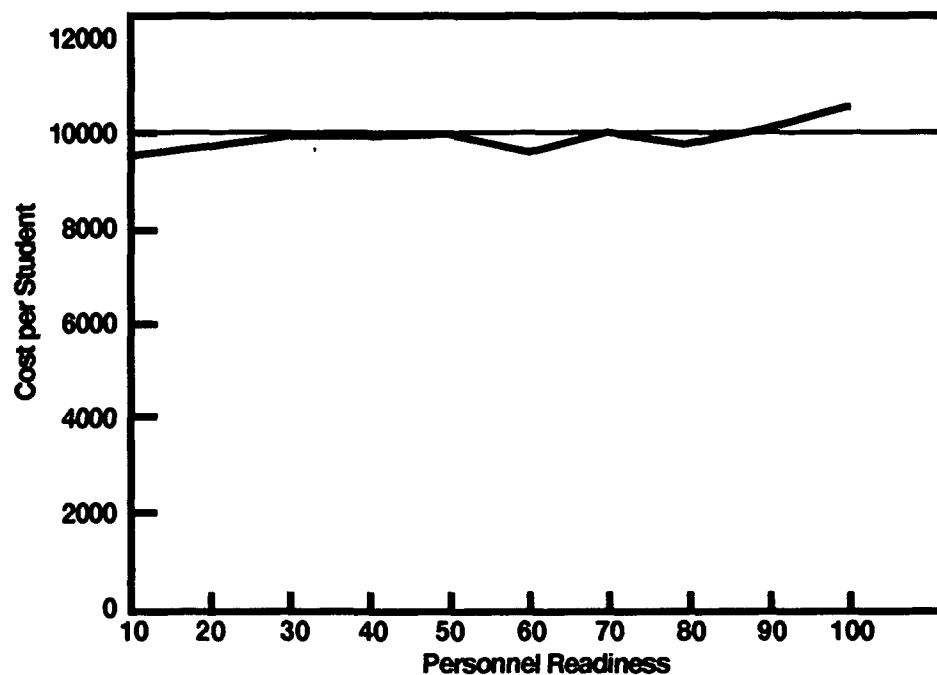


Figure 3. Average training cost per student for different levels of personnel readiness.

Table 2

Most Expensive Ratings

Ratings	C = 3	C = 2	C = 1
Machinists Mate (MM)	2.14	5.76	16.06
Electronic Technician (ET)	2.26	4.74	12.90
Explosive Ordnance Disposal Specialist (EOD)	2.72	3.76	4.90
Operations Specialist (OS)	2.85	5.06	7.85

Benefits

Using the model the Navy can, for the first time, relate the cost of skill training to mission readiness. The problem has always been complicated by the cross-utilization of skills, the reusability of skills on later tours, and the difficulties of getting and using both training cost and fleet readiness data. In the past, the Navy was growing and had the resources it needed, but that has now changed. The model will play an important role in planning training requirements in the current atmosphere of constrained training resources.

The model will be presented at the Operations Research Society of America/The Institute of Management Sciences Conference in October 1994 and will be submitted as a research paper.

References

Thompson, T. J., Krass, I. A., & Liang, T.T. (1991). *Quantifying the impact of the Permanent Change of Station (PCS) budget on Navy Enlisted Personnel Unit Readiness*. (NPRDC-TN-91-16). San Diego, CA: Navy Personnel Research and Development Center.



Independent Research Projects

Responses on Computer Surveys—Impact of Social Situation and Information Verification

Paul Rosenfeld

Objective

This study attempted to directly address the inconsistency of previous computer versus paper-and-pencil surveys. The objective was to examine the impact of the social situation and information verifiability on responses to computer surveys. Based on previous research it was hypothesized that the nature of social situation and the verifiability of the survey information might explain why responses on computer surveys sometimes lead to more, less, or equal levels of socially desirable responding as compared to paper-and-pencil surveys. Given the Navy's increased dependence on computer surveys, it is important to understand under what conditions heightened socially desirable responding is likely or not likely to occur.

Benefits

The benefits expected from this study relate to a clarification of the conditions under which computer surveys will produce responses equivalent to paper surveys. Based on the results of the completed study these are: (1) when the responses are anonymous and (2) when the computer's link to a larger database is not made salient.

Under these two conditions (which are the common way that computer surveys are administered), the conclusion that computer surveys yield essentially equivalent results to paper surveys is supported. However, a limitation and caution in the use of computer surveys is now warranted. Under conditions of identifiability and where the computer's linkage to larger databases is made salient, the present study suggests that responses to computer surveys may be more influenced by socially desirable motives than their equivalent paper conditions.

Long Term Retention of Factual Information and Mental Skills

*John Ellis
George Semb
Barbara Wyman*

Objective

This project focuses on three research issues. The first addresses memory for semantic content learned in school with different characteristics and task requirements. Specifically, retention of college course content with different task requirements is being examined. Part of this investigation involves assessing how knowledge structures change over time. The second research issue involves comparing memory for episodic information with memory for semantic information learned during a college course. Specifically, information about the course (e.g., course procedures, teacher's name, classroom environment) is being compared with memory for the course's semantic content. The third issue concerns memory for course semantic content for students who served as peer tutors compared to students who simply completed the course requirements. Tutoring can be viewed as a form of overlearning and may result in enhanced retention.

The research objectives are to (1) determine retention curves for college course content with different task and task component requirements, (2) compare retention of episodic and semantic information acquired during the same time period, and (3) examine the effects on retention of serving as a peer tutor

Benefits

This research could provide Navy training designers, developers, managers, and instructors with principles and guidelines for enhancing retention of factual information and mental skills. Enhanced retention may lead to better performance of job skills, increase the productivity of personnel coming to the fleet from school assignments, and improved tactical decision making. If successful, the research could transition into ongoing 6.2 work on complex cognitive skills and/or 6.3 work on classroom instruction.

Individual Differences in Information Acquisition and Processing Style

Robert F. Morrison

Objective

The objectives of this research are to (1) identify the variation in schemata that individuals with different decision-making styles use to acquire and process information in dynamic decision-making (DDM) situations, and (2) develop a preliminary model of situational and individual differences that influences individuals to vary their approaches to DDM using different decision strategies than other decision makers.

Benefits

The results of this work may provide new insights about alternative approaches to effective DDM and obtain enhanced user acceptance for use in the construction of decision aids under several 6.3 manpower and personnel tasks.

Brain Activity and Cognition: Advanced Signal Analysis Using the Wavelet Transform

Leonard J. Trejo

Objectives

A systematic comparison of wavelet transforms to time domain and principal components analysis (PCA) of event-related potentials (ERPs) was performed using single-trial data from a radar signal detection task. This work involved comparing wavelets to other methods in linear multivariate regression models and neural network models of task performance.

Benefits

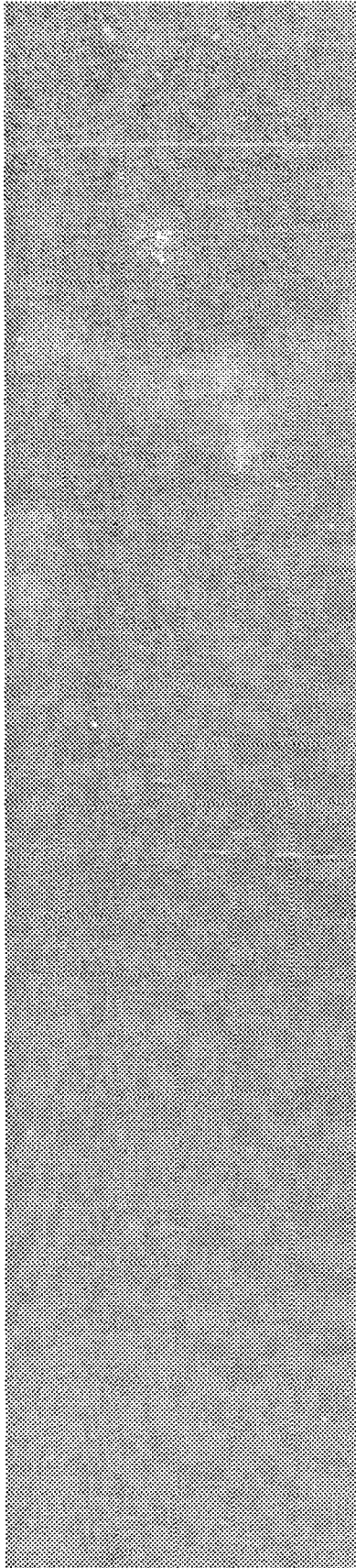
The models, which were cross-validated using hold-out samples of data, showed that the wavelet transform was a more efficient way of extracting features of the ERP than PCA for the purposes of task performance prediction. Wavelet methods also led to better generalization (less shrinkage) in linear regression and neural network models than either PCA or time domain representations. Finally, wavelet methods led to the most stable learning curves and least over-learning of the data in neural network models of task performance.

A complete and systematic comparison of neural networks and regression models based on ERP time domain, wavelets, and PCA was completed. The work with neural networks was valuable in that it demonstrates that a linear regression model of task performance based on wavelet transform coefficients performs as well as or better than neural network models. No clear advantage was seen in using a neural network to predict task performance after the wavelet transform had been computed.

Progress was also made in wavelet software development. A revised extended version of NPRDC's core wavelet transform software for implementing undecimated 1-dimensional transforms was completed. In addition to forward transforms, the revised software computes inverse transforms. This capability will allow for time-domain interpretation of ERP features that have been identified in the wavelet domain.

From a neuroscience standpoint, this research is basic in that it seeks to characterize fundamental neural processes in terms of a new set of basis functions, wavelets, which are distinct from traditional component or Fourier analyses. It is expected that wavelets will lead to ERP and electroencephalograph (EEG) measures that are more sensitive and have higher diagnostic value than traditional peak and latency and fast Fourier transform measures. From a mathematical standpoint, this research is application-oriented by bringing new methods to bear on a known problem.

From a military standpoint, the need for methods of enhancing human performance in complex combat systems is clear. Human error, variability, and inefficiency are major causes of performance failures in sonar monitoring and in many other systems. One benefit of this research for the Navy would be the development of EEG and ERP measures that are useful for short-term prediction of human performance in combat systems. Such measures would be of value to real-time operator performance monitoring for command and control purposes. Another benefit would be in the discovery or clarification of the relationships between ERP structure and cognitive processes. Such knowledge would be of value in the analysis of human performance in new systems, in systems with recognized deficiencies, and in the evaluation of changes in operator strategies produced by training or experience.



Independent Exploratory Development Projects

Comparison of Back Propagation Artificial Neural Network, Polynomial Regression, and Logistic Regression Models for Computer-Simulated Personnel Selection Data

W. A. Sands

J. Folchi

Objectives

This research project extends previous work on Artificial Neural Networks (ANNs) by examining linear and quadratic functional forms as well as a cubic functional form. In addition to the linear regression model (POLY1), three other types of regression models were studied: (1) a second-degree polynomial regression model (POLY2), (2) a third-degree polynomial regression model (POLY3), and (3) a logistic regression model. Finally, three alternative back propagation models were also investigated.

A major strength of back propagation models is that the researcher does not need to know the underlying functional form. The back propagation model will *learn* the appropriate functional form, using representative training data.

Benefits

The results obtained in this research are quite encouraging, and confirm the impressive results obtained in earlier work. It is important to note that the back propagation models we developed in this study used a single, simple configuration. In a real-life application of back propagation, the configuration of nodes and the parameters would be varied to determine the best choices for the particular problem being addressed. In spite of this lack of fine-tuning, the back propagation models performed quite well on the evaluation (cross-validation) samples. The back propagation approach to artificial neural networks offers a very powerful tool and should be considered for use by personnel researchers.

The use of artificial neural networks should enhance the accuracy of personnel selection models. In the Navy, this improvement is expected to payoff in improved screening, decreased training attrition, and increased on-the-job performance.

Comparing Minority and Majority Exclusion Rate Differences Over a Cut Score Domain

J. Folchi

Objectives

The four-fifths rule is often used to determine whether a personnel selection instrument excludes a higher proportion of minority group members than majority group members. However, the use of alternative decision rules, in conjunction with a *cut score domain* containing the cut scores most likely to be used during the operational life of the instrument, may contribute to the development of selection procedures that are less biased during that period. The first objective of this research was to compare the four-fifths rule's ability to correctly detect selection bias with those of two alternative procedures, using simulated data sets in which the cut score domain contained exactly one cut score. The two alternatives were the Anderson-Darling test and the normal approximation to the binomial. A secondary objective was to compare the correct decision rates of the three procedures when the cut score domain contained more than one cut score.

Benefits

This research provides a basis for improving the detection of bias in personnel selection instruments used by organizations that select their employees from a large pool of applicants. The conditions under which the three alternative methods perform best are identified, thereby providing a basis for choosing the method best suited for a particular personnel selection problem.

An Examination of Cognitive and Motivational Effects of Employee Interventions

John P. Sheposh

Objectives

The objective of this study was to (1) assess the level of empowerment among employees, (2) determine the extent to which certain contextual factors are related to empowerment (i.e., do differentially empowered employees perceive specific organizational and individual factors differently?), and (3) assess differences in perceptions of factors relating to the implementation and use Total Quality Leadership (TQL) among differentially empowered employees.

Benefits

The results from this study provide further support for the cognitive model of empowerment. The fact that both motivating potential of the job and empowerment contributed to the perception of job satisfaction suggests that the cognitive model is more comprehensive and reflective of a wider set of influences than those contained in the job characteristics model. Furthermore, the finding that the most highly empowered employees were the more satisfied held over a 2-year span. Also consistent with the cognitive theory of empowerment was the finding that highly empowered employees were more favorably disposed and involved in the implementation of TQL. Individuals who see themselves as having higher competency levels are more willing to be involved in such efforts as TQL. Lastly, the results depict the causal relationship between these variables.

Cultural Diversity in the Workplace

Jeffrey D. Houston

Objectives

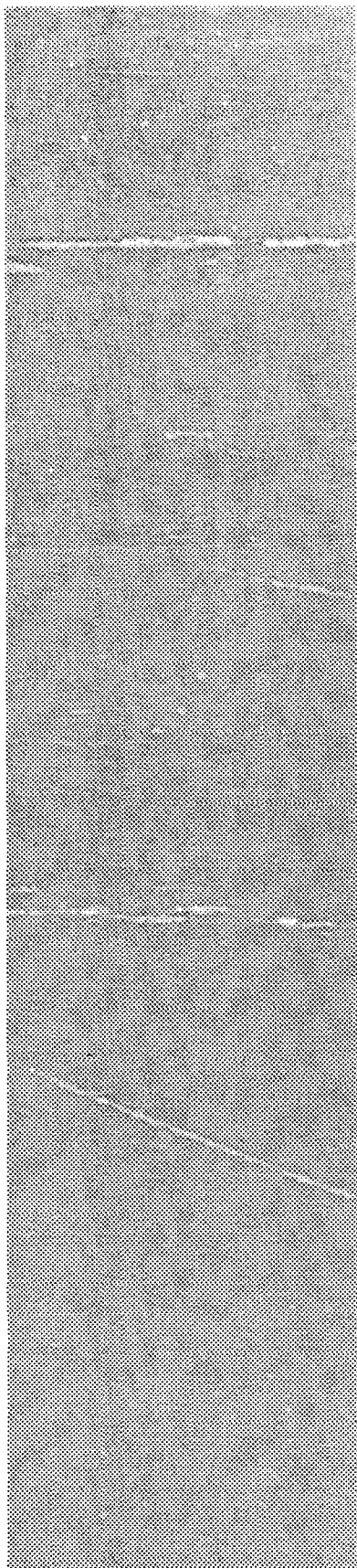
Approximately 7,800 civilian employees in the DON were selected to participate in this research. Respondents were randomly sampled within subgroups. The subgroups included race, command, supervisory status, and job status (i.e., blue collar/white collar). The respondents came from the Naval Sea Systems Command, Naval Air Systems Command, Naval Supply Systems Command, and Space and Naval Warfare Systems Command. The racial groups identified for participation were White, Hispanic/Latino, African American, Asian/Pacific Islander, and Native American.

Each respondent received a 16 page survey which addressed: (1) work beliefs, views of the organization's social responsibilities (i.e., the extent to which the organization is responsible for meeting the needs of specific populations within the organization); (2) job attitudes (i.e., facets of work and organizational satisfaction, organizational commitment, organizational citizenship, and turnover intentions); (3) job and organizational characteristics (i.e., perceptions of organizational and social tolerance, characteristics of the job, and perceptions of fairness in the organization); and (4) developmental/mentoring relationships. The respondent was supplied with a self-addressed postage paid envelope to return the survey to the researcher. A response rate of 43% was obtained.

The research was divided into two separate components. The first component was directed at identifying key areas in which cultural groups (i.e., race, gender) differ. Analyses were conducted with the Multi-Variate Analysis of Covariance (MANCOVA) routine in Statistical Package for the Social Sciences (SPSS) for Windows. The second component was directed at determining whether the relationships between the variables differ as a function of cultural group. A conceptual model was developed and tested using structural equation modeling techniques.

Benefits

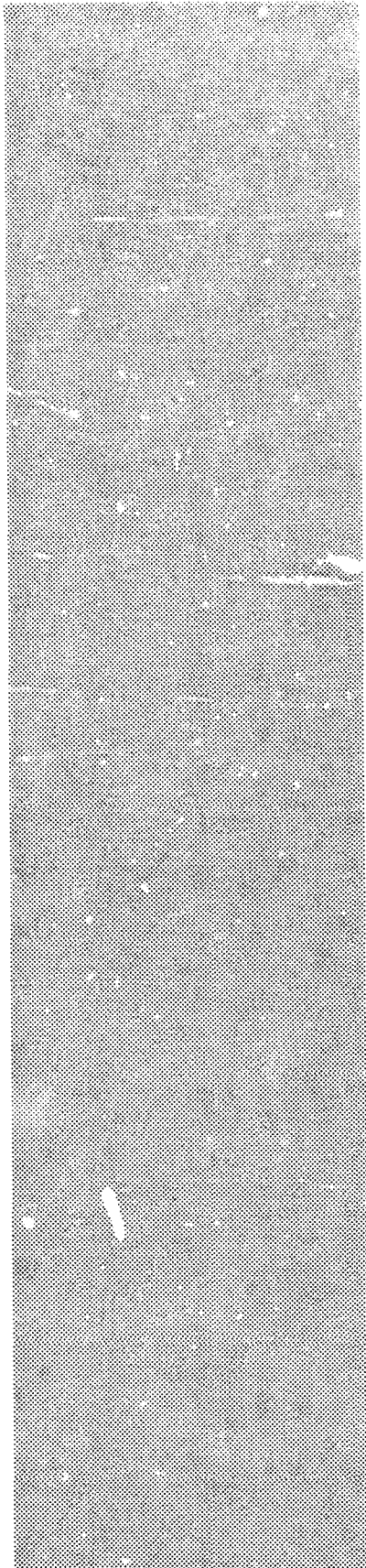
The results confirm the research hypothesis that the extent that the organization is perceived as sensitive to cultural differences has an impact on a worker's satisfaction with the organization and his or her stated intention to remain with it. In addition, race did moderate the relationships between the variables. For example, organizational tolerance does have a direct impact on perceived fairness for African American and Hispanic employees while the impact of organizational tolerance on perceived fairness is mediated by perceptions of procedural fairness for White and Asian American employees. Similarly, social tolerance has differential effects on perceived fairness, organizational satisfaction, and turnover depending upon race.



Transitions

6.1 project *Individual Differences in Information Acquisition and Processing Style* is expected to transition to 6.3A.

6.2 *Enlisted Requirements Model* is expected to transition to 6.2 project *Training Resource Allocation Technologies*.



Publications and Presentations

Borack, J. (Editor). (1993). Conference on applications of artificial neural networks and related technologies to manpower, personnel, and training: Proceedings (NPRDC-AP-93-10). San Diego, CA: Navy Personnel Research and Development Center.

DeYoung, P. H. (1993, August). *The effects of group size and expected level of productivity gain sharing success on motivation, job performance and job satisfaction*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.

Fitch, M. A., & Semb, G. B. (1993). *The ASK model of peer tutoring: Theory and research* (NPRDC-TN-93-7). San Diego, CA: Navy Personnel Research and Development Center.

Folchi, J. (in process). Comparing minority exclusion rate differences over a cut score domain. *Applied Psychological Measurement*.

Folchi, J., & Sands, W. A. (in review). *Comparison of artificial neural network back propagation models with polynomial and logistic regression models for personnel selection* (NPRDC-TN-94-XX). San Diego, CA: Navy Personnel Research and Development Center.

Glaser, D. N. (1993, August). *The effects of complexity and amount of workload on strain and performance*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.

Krass, I., & Sorensen, S. (in process). Optimal enlisted training readiness model. *Naval Research Logistics*.

Krass, I., & Sorensen, S. (1994, October). *Optimal enlisted training readiness model*. Paper to be presented at the Operations Research Society of American/The Institute of Management Sciences Meeting, Detroit, MI.

- Nebeker, D. M., & Tatum, B. C. (1993). The effects of computer monitoring, standards, and rewards on work performance, job satisfaction, and stress. *The Journal of Applied Social Psychology*, 23, 508-536. (Work done in FY85/86).
- Riemer, R. A. (1993, August). *The effects of productivity gain sharing and employee involvement on job performance*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.
- Rosenfeld, P., & Booth-Kewley, S. (in process). Impression management and computer surveys. In J. Beard (Ed.), *Impression management and technology*. Westport, CT: Greenwood.
- Sands, W. A., & Folchi, J. (in process). Comparison of back propagation and regression models for personnel selection. Williamsburg, VA: U.S. Coast Guard.
- Sands, W. A., & Wilkins, C. A. (1993). A comparison of ordinary least-square—linear regression and artificial neural network—back propagation models for personnel selection decisions. In J. I. Borack (Ed.), *Applications of Artificial Neural Networks and Related Technologies to Manpower, Personnel, and Training* (NPRDC-AP-93-10). San Diego, CA: Navy Personnel Research and Development Center.
- Semb, G. B., & Ellis, J. A. (in process). Knowledge taught in school: What is remembered? *Review of Educational Research*.
- Semb, G. B., Ellis, J. A., Matheson, C., Fitch, M. A., Kuti, M., & Parchman, S. (1993). *On-the-job training practices on Navy ships* (NPRDC-TR-93-5). San Diego, CA: Navy Personnel Research and Development Center.
- Tatum, B. C. (1993, August). *The effects of fixed versus continuous improvement goals on productivity and affective reactions*. Paper presented at the annual convention of the Academy of Management, Atlanta, Georgia.
- Tatum, B. C. & Nebeker, D. M. (1993, June). *The effects of fixed versus continuous improvement goals on productivity and affective reactions*. Paper presented at the Fifth Annual Convention of the American Psychological Society, Chicago, Illinois.

Tatum, B. C. & Nebeker, D. M. (in process). The effects of system control and feedback errors on job performance and affective reactions. *Academy of Management Journal*.

Trejo, L. J. (1993a, January). *Decorrelation and energy compaction of evoked potentials with behavioral covariance criteria: A comparison of peak measures, principal components analysis, and the discrete wavelet transform*. Presentation to the Office of Naval Research Biopsychometric Assessment Program Review, San Diego, CA.

Trejo, L. J. (1993b, November). *Quantitative relationships between event-related potentials and human performance*. Invited presentation to the meeting on EEG in Basic and Applied Settings, Air Force Human Engineering Laboratory, Dayton, OH.

Trejo, L. J., & Shensa, M. J. (1993a, November). Linear and neural network models for predicting human signal detection performance from event-related potentials: A comparison of the wavelet transform with other feature extraction methods. *Proceedings of the 1993 International Simulation Technology Conference, SIMTEC93/WNN93/FNN93*. (153-161).

Trejo, L. J., & Shensa, M. J. (1993b, November). Pattern recognition neural networks for human event-related potentials (ERP): A comparison of feature extraction methods. In J. I. Borack (Ed.), *Applications of Artificial Neural Networks and Related Technologies to Manpower, Personnel, and Training* (NPRDC-AP-93-10). San Diego, CA: Navy Personnel Research and Development Center.

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